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Improvising the Intra -Terminal Vehicle Movement in a Container Terminal

By

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Abstract

The container terminal forms the maritime backbone to cater for the container trade influx. The containerized cargo enhanced the cost-effectiveness to transporters, traders and other stakeholders involved in the supply chain. However, the major problem to handle containerized cargo is their storage and handling on container terminals. Around the world, container terminals have witnessed different bottlenecks in the operational flows in their container yards. Prior studies conducted disclosed that various factors influence container terminal efficiencies.

Sea container terminals play an important role in globe-spanning supply chains because of a huge increase in containerized goods and a rapid growth in world trade. Container terminals should be able to handle big ships in the quickest amount of time, at reasonable prices, and with massive call sizes. In response, port authorities, terminal operators and shipping liners are investing in modern technologies to enhance operational efficiency and container handling infrastructures. Container terminals experience challenging research problems that have attracted much attention from the academic communities. The concentration of this research is to highlight the recent container terminal developments that can be classified into three domains: (1) innovative terminal technologies that improve the Intra -Terminal Vehicle (ITV) Movement, (2) new models and directions for existing research domains, and (3) emerging areas in container terminal studies.

The research seeks to comprehend and try to solve certain challenges that facing container terminals. The containerization growth has created various challenges for ports such as higher requirements on infrastructures and terminals. Many container terminals are reaching their capacity limits and gradually resulting in port congestion and traffic. The needs of managing complex systems like container terminals require new methods for finding solutions by introducing technologies and techniques to improve the Intra-Terminal Vehicle (ITV) Movement. The general question handled is: How can container terminals improve the intra-terminal vehicle movement?

The findings of the study suggest that the application of technologies can be justified in their application for improving performance in container terminals and the Intra -Terminal Vehicle (ITV) Movement. The applications of technologies promote the objective of finding the best alternative to improve capacity instead of the acquisition of extra resources or physical expansion. Besides, the applications of technologies are recommended to be a feasible method

for container terminal and the Intra -Terminal Vehicle (ITV) Movement when operating under uncertainties. The researcher has carried out research based on both quantitative and qualitative methodologies which may prove to be useful for terminal operators. This research focuses on containers and in future, there can be technologies used for improving performance for specialized terminals concerning the cargo type handled by them.

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Chapter 1 - Introduction

1.1 Introduction

Containerization is development which emerged in the mid-20th century and transiting costs were drastically reduce due to elimination of the unwanted handling process. The container terminals have invested in their container handling equipment fleet, implementing sophisticated terminal operating software and storage yards for efficient handling of containers. The approach of container terminals is to achieve lower handling cost, quick retrieval and storage of the containers, optimal use of the equipment fleet, etc. This research paper aims to address the challenges that intra-terminal vehicles movement is facing also referred to as the yard feeding. Besides the research will also explore options that can be adapted with the innovations happening across the port sector for enhancing the operational flow in container terminals.

1.2 Background

Containerization improves efficiency and transport speed by minimizing handling processes and packing requirements at all points of transfer, that is between road, port, and rail rather than loading and unloading each piece of transport commodity to or from ships in a labor-intensive manner. The aim to improve their productivities on vessels to deal with larger ships with bigger call sizes in the same timeframes. In today's terminal operations, Intra -Terminal Vehicle (ITV) Movement plays a critical role because it supports equipment control, planning, and scheduling. More and more activities are recently carried out by ITV. These activities should be well-aligned to the operations such as equipment dispatching, yard planning and ground decisions to minimize risks and costs.

Container terminals operators (CTO) are facing the challenge of continuous rise in the container volumes; therefore, they have adopted new techniques and technologies for better controlling systems. The CTOs can reduce bottlenecks by procurement of new technology or investing for physical expansion. However, this does not work for every terminal as majority CTOs are facing the space constraint such as the container terminals situated particularly in Europe. The addressal of space constraints are dealt with the automation, upgrading the terminal operating software (TOS), utilizing complex storage strategies, or through smart commercial policies (such as pricing strategy for container dwell time).

The researcher focuses on the yard feeding rate of the ITVs and ways to enhance the movement in the container yard. The existing models that are utilized in evaluating and planning container terminals and Intra -Terminal Vehicle (ITV) Movement such as traditional simulation, queuing theory and linear programming has had mixed results (Bruzzone 1999). Major CTOs such as APM Terminals, DP World, CMA CGM Terminals, TIL (MSC), Yilports, Transnet have engaged themselves in building terminals with forthcoming technology (green equipment, BOXBAY, etc.), latest TOS/yard management modules versions installed, physical expansion phases. There are two main categories in container terminals which are automated and traditional, both have their own challenges.

1.3 Problem Statement

Container terminal operators are facing the pressure from accelerated technological disruptions such as increasing size of the container vessel, advancement in the equipment/TOS, high variability of call size and the growing container volumes. The major challenge highlighted in this research is of the yard feeding which is the movement of the intra terminal vehicle movement between the quay area – container yard. This issue was emerged due to the following:

1. **Higher quay crane productivity against the yard feeding rate**
   The STS operators are highly skilled, and the operational speed has been always more than the yard feeding rate. The average waiting time of ITVs in the quay area has been less nowadays. Even the OEM providers are making advancement in the quay cranes.
2. **High length of travelling distance between container yard and quay area**
   CTOs such as in the Asian region have stated the travelling distance for ITV is higher as the size of terminal is large, quay areas are situated far away from the container yard. Another sub-factor which contributes to this issue is the speed of the ITV is limited by the HSSE team of every terminal.
3. **Equipment Breakdown or Failure**
   The container terminals across the globe are utilizing container handling equipment for the basic functions such as loading/unloading the vessel/ITV/client truck trailers and handling the containers for storage. The CTOs must deal with the unforeseen equipment breakdown because of the wear-n-tear, technical glitches. To reduce the equipment breakdown or failure the terminals are using the maintenance strategies, however, cannot be eliminated totally. The impact of equipment breakdown or failure will result in break the flow of ITV movement and increase the yard congestion (traditional terminal) or slowing the ITV movement thus affecting the yard feeding rate.

4. **Complex yard planning or storage strategy**

The ITV fleet is distributed into yard pools and are utilized in dynamic manner, however, there has been observation by many terminal operators that ITVs average waiting time is high due to the complex storage strategies. In real time scenario, the average waiting time is increased due to reshuffling on the spot when ITV is waiting for the drop-off, loading resulting in a slower yard feeding rate. These situations are considered under the wasted opportunity principle. In traditional container terminals, the yard is a choking point for TTs i.e., the problem of yard congestion is result of storage strategy. In automated terminals, the ITV fleet is less and due to complex storage methods, the retrieval of containers takes time. The terminal planners need to be vigilant while selecting and implementing of the storage strategy as to reduce the inter block movement of yard cranes to serve maximum from one container block.

5. **Terminal Layout**

Design and Infrastructure is the basic essence of any building/structure, in this research the container terminal layout has been considered a challenge/issue. The terminal layout of any container terminal is a fixed structure and cannot be changed in short of span of time with less investment. There have been many ports who are working with their clients owning the terminals in their premises to jointly finding solution for the impact of terminal layout on the movement of ITV. It was found that some terminal professionals don't count this as an issue, however, the researcher argues that terminal layout is costing the CTO's crucial money and time.

6. **Terminal Operating System (TOS)**

Artificial intelligence in TOS has a long way to reach human understanding and the ability to make decisions. There is a simple rule of nature that says to achieve something, a loss is sure to endure whether small or big. Another example of TOS limitations is the automation of TOS, it is there are blind spots where they cannot process or are not able to make decisions. Most of the container terminals are upgrading their TOS with new functions to manage the complexity, however, even after doing so, the TOS is falling behind. The terminal planners are frequently using a distribution strategy for managing ITVs by making their yard pools. The continuous dynamic utilization of the ITVs will ensure that planners do not need to make the yard pools every time a new vessel is berthing on the container terminal. Another reason is the data sharing between terminal and shipping lines, the yard plans are only available to the

1.4 General objective

The main research objective for the study is how the movement of the intra terminal vehicle can be improved in the container terminals.

Main Question: How can container terminals improve the intra-terminal vehicle movement?

Sub-questions:

1. How does ITV movement is playing a key role in the efficiency of container terminals?
2. What factors affect the Terminal operating software?
3. Are there any alternative methods to improve ITV movements?
4. How will the container terminals operate without ITVs for hassle-free container movement?

1.5 Organization of the study

In reference to **Figure 1 - Thesis Structure**, Chapter 1 is the introductory chapter that explained the background and motivation of the research. It also discussed the critical research questions and study objectives. Also included in chapter one problem statements underlining the issues. Chapter 2 states the theoretical framework describing the variables needed for the data analysis and why they play role to define the dependent variable. The agent technology and technological disruptions is to support the TOS decision support system and proposition for CTOs. Chapter 3 presented the overall research approach and evaluated the research methodology used to collect primary and secondary data. It also explored the sampling type used to identify research participants and the analytical framework employed to derive the sub-findings for each sub-question. The chapter also discussed the use of the purposeful sampling technique in selecting research participants. This justifies by the highly technical nature of the research, focusing on industry experts who were considered to possess the required knowledge. Another method used is based on the minimization model, which aids in understanding the working of agent technology. Chapter 4 presented data and analysis on the first and last sub-question. The chapter 4 states the minimization model and how they can include to run it with their terminal operating software. Chapter 5 combined the sub-findings into the overall research findings, conclusions, and recommendations to substantiate the main research question. The chapter then concluded by showing the connection among the various variables. The last section of this chapter outlined the various areas for added research. The areas must be pursued to gather further insights on the related subject matter.

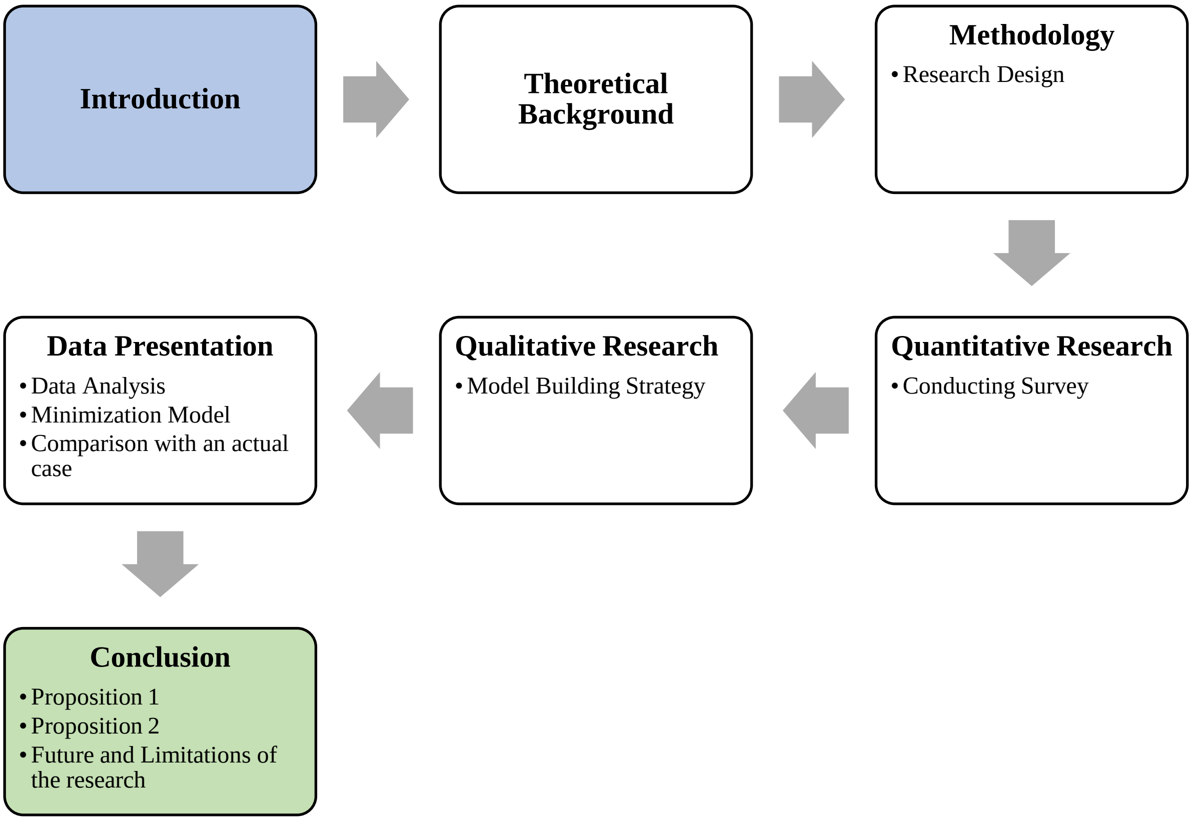


Figure 1 - Thesis Structure

Chapter 2 – Theoretical Background

2.1 Introduction

In this research the focus remains straight on the improving the movement of intra-terminal vehicle. This chapter of the research is describing the importance of ITV in the terminal when it comes to operate a container terminal followed by the types which have been deployed in today's era. The container terminals are a complex gateway through which trade is flowing, the essence of storing and handling of the same always remains a challenge. The reason is simple to increase the economic benefits and pass on to the landside/seaside clients. The research is reviewing the gaps such that the container terminals facing issue of slow yard feeding will either reduce or will aid in triggering a response to address the issue. The research also states focuses on building a minimization model which needs to be improving the visibility of terminal operating software.

The researcher has investigated technologies which are currently in the design or trial phase which might enhance the terminal operations. The industry is skeptical by the saying "Is the technological disruption a key to the solution or is it too fast to adopt it?". The opinion is varying as per the company visions, the deployed workforce, the users, etc. There cannot be one solution which can solve everything. However, the researcher believes that adapting the technological disruption will be best to move forward with. The trade influx is increasing daily with a rising demand for lowering the operational cost and opportunities for business growth can be expected. The incorporation of a disruptive technology in the existing line of services will aid in the customer transition and serve as a major to key address the basic problems.

2.2 Container Terminal

Several vessels are often berthed alongside in a port container terminal, and each vessel is served by multiple quay cranes, which are supported by numerous yard cranes in the yard. In **Figure 2 - Typical flow of containers in terminal operations**, displays a typical container flow in a container terminal. When a vessel berthed at the terminal, containers are typically emptied from the vessel, mounted onto trucks (known as intra-terminal vehicles) by quay cranes, then unloaded by yard cranes in different container blocks across the container yard for storage and stacking. Export containers loaded onto ITVs by yard cranes in the yard are unloaded at the quay and loaded onto a vessel by quay cranes during the loading procedure. The dispatching and scheduling of equipment is a critical planning concern for terminal planners in both loading/unloading operations. Terminal planners establish the locations of storage areas for the containers to be loaded aboard the vessel a few days before the vessel arrives (loading sequence), and then the containers to be placed in the vessel bay. They show the order of unloading and loading containers for the vessel, as well as the quay cranes to be assigned to the vessel, a few hours before the vessel arrives. Once handling activities begin aboard the vessel, quay crane handling jobs will generate tasks for the ITV and yard crane handling jobs. Transportation jobs are assigned in real time to highly mobile vehicles via voice communication or a wireless computer network. In recent years, the ITV fleet is divided into a yard pool. These yard pool are assigned tasked according to the vessel berthed and can be utilized in dynamic manner. Following to this the terminal planners are needed to predict and plan a yard crane schedule for the inter-block movement of the yard crane. This ensures a minimised waiting time for the ITVs in the yard and the continuous flow of containers between the quay and container yard leads to good yard feeding.

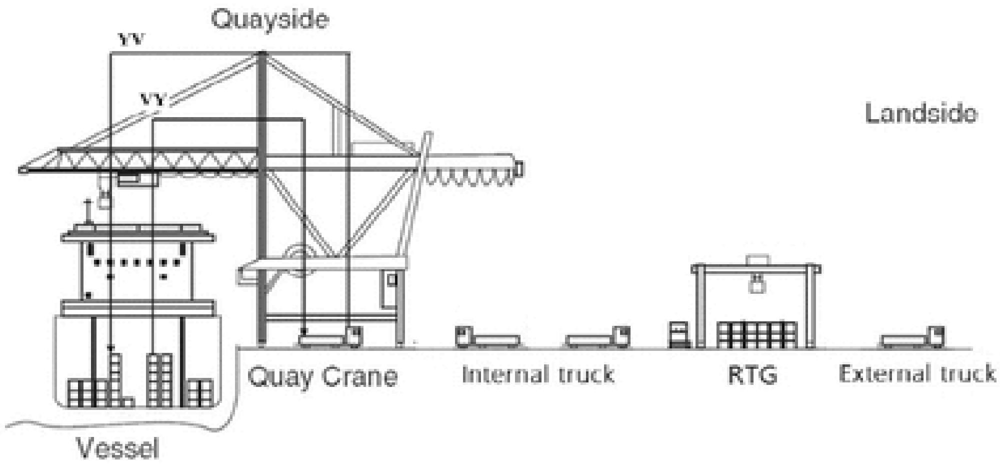


Figure 2 - Typical flow of containers in terminal operations

2.3 Intra Terminal Vehicle (ITV)

Intra Terminal Vehicle — A vehicle used to transport containers within the terminal yard, quay area, or till gate procedures. These vehicles are referred to as intra-terminal vehicles (ITV). ITVs have a substantial influence on container terminal efficiency, either positively or negatively. The ITVs are operated by container terminal operators (CTOs) in designated yard pools (each yard pool consist certain number of ITVs). The distribution of ITV fleet in yard pool is required for a variety of reasons, including reducing chaos/traffic in the yard or quay area, preventing mishaps (to a certain extent), eliminating manual errors in the case of manned ITVs, and optimizing their utilization.

In a nutshell, container terminals are akin to anthills or ant colonies in terms of the total transport chain. The ants serve as ITVs, keeping meals or other goods in several areas throughout the anthill or ant colony. The storage procedures at anthills and container terminals are complex, requiring ants and ITVs to traverse the shortest distance feasible to preserve energy and minimize operational time.

2.3.1 Types of Intra Terminal Vehicles(ITVs)

1. **Tractor Trailers/Terminal Tractors (TT)** – They are primarily used in transporting the containers between quay area and container yards. Major container terminals operators prefer TTs in there ITV fleet due to their robustness and productivity. The drawback of the TTs is that manual errors can take place such as yard congestion, mishaps in the yard (specifically on the blind spots) and speeding violation if the ITV fleet is hired on a 3rd party contract.

Figure 3 - Tractor Trailer (TT) or Terminal Truck

2. **Straddle carriers (SC)/Straddle trucks** – It is a form of ITV in which the container loads are carried on the top lifting points with help of container spreader (by straddling), as opposed to TTs which carry them on top of the trailer chassis. Straddle carriers provide an operational benefit and decrease terminal equipment since they are utilized in stacking containers, transporting containers from the quay area to the container yard, and at some terminals, assisting in the loading and unloading of trailer beds. Many terminal operators and OEM suppliers believe that SCs are fast and do not require additional cranes for loading and unloading. Straddle carriers can only stack containers up to a height of 3 or 4 units, and the equipment cost is relatively high because it is still new technology for many CTOs to deploy.

Figure 4 - Straddle Carrier

3. **Automated Guided Vehicle (AGV)** – AGV is like TTs, however it is unmanned and managed remotely by transferring containers from the dock area to the container yard. The terminal operators are conducting tests. AGVs are gaining popularity and acceptance among terminal operators because to their low mistake and accident rates. The drawback here is that further investment in AGVs and ancillary equipment is required (refueling, control).

Figure 5 - Automated Guided Vehicle

2.4 Variables

The researcher considers has distinguished the variables in dependent and independent, to identify and analyze the relationship between them. The variables described in this section are accounted for the quantitative research. The purpose for having this many variables is necessary to investigate the initial impact on the movement of ITV. They were identified based on the challenges/issues stated in the section 1.5. As discussed in the section 2.2 for **Figure 2**, all the variables are distributed in the terminal supply chain and understanding the reasons for making such impact on the ITV movement will clear the idea of rejection of variables in the further study. In statistical terms, the independent variables are also referred to as the predictors and aid in the forecasting of the dependent variable.

2.4.1 Dependent Variable

The research is based on the movement of the intra-terminal vehicle (ITV) movement; therefore, the yard feeding has been considered as the dependent variable. The term yard feeding is generally used for when ITV is making the movement between container yard and quay area. The major ports and terminals have been working closely with the OEM providers to improve the technical aspects or agility of the equipment they deployed in their respective terminals. However, it is not enough as the yard feeding is affected by many factors such as the quay crane productivity, length of travelling for one single ITV, terminal operating software capabilities, etc. This dependency clearly states that the yard feeding is to be considered as a dependent variable.

2.4.2 Independent Variables

a. **Layout and infrastructure**

Each container terminals are having its own layout either parallel or vertical because of the geographical location they are situated in a city, port town, etc. This general factor aids the head planners of the terminal to suggest the expected terminal productivity they can achieve in the years to come irrespective of the economic trade coming in or out. The container terminal operating companies can decide on the budgeting of their finances that where can be investment made most to ensure achieve the ROI. Once the operations are initiated the flaws in the implementing the layout or changing the infrastructure is a high-dollar affair to the investors. Considering the container terminal having a good influx of trade will be create more hurdles down the operational level, where the importance of ITVs in the terminal is affecting them a lot. Many terminals are dealing the hurdles of infrastructure and type of layout they have implemented in their respective terminals. The result of which the problems like high length of travelling from container yard to quay area goes up to one km for just one way. The CTOs are losing the cost effectiveness, increasing the wear n tear on the assets deployed and the golden minutes of productivity. Some terminals on the other hand running tight in space decreasing their terminal efficiency as their container yards are almost full due to heavy container volumes. Some CTOs are not concerned with the layout of container terminals, and some are by stating the ease of operations for the ITV movement in the yard. Currently, there are two famous layouts being used which are parallel or vertical in the container terminal. The researcher classified the container terminals into traditional operating and automated operating terminals.

Decision for choosing of equipment and layout of terminal

To build smooth transport chains, in container terminals there are various research carried out and the motivation was for this research to be adapted from creatures in the wild. In today's world if what we see is heavy automation and technological appliances/equipment being used. The fundamentals on which they are originated are animals. An example of robotics in warehouses, or automated stacking cranes are using the principles of an ant colony. The researchers have understood how and why ants are always finding the shortage way back and leading their fellow mates in the shortest direction possible to save energy. The Ant Colony Optimization models used in the IT, maritime, logistics sector has made it more interesting but a lot of complexity due to lack of decision making in the AI system Wang (2015).

Two key points must be considered for choosing the right equipment for the terminal layout that is implemented. There are two types of layouts parallel and vertical which are currently being used by the terminal operators. In the parallel layouts are suitable for equipment which are manually operated because in manual operations there are certain possibilities of congestion in the yard, chances of error, double task assignment for the same ITV, etc. The vertical layout of the container terminal is suitable with a separate set of equipment due to ease of mobility. Traditional container terminal prefers parallel & Automated container terminal prefers vertical layout. The basic reason for this is due to the choice of equipment deployed, manpower cost and efficiency. Other reasons are that inter-block movement of the yard cranes (Rubber tyred gantry, Automated stacking crane) and of the ITVs moving under the yard crane has reduced the number of handlings per container. The traditional terminals that have parallel layout has also observed that yard cranes are not overworked resulting in a breakdown. The automated terminals do not fairly distribute the operational load resulting in the known limitation of automation and the slowness in operation is offset by the optimization of available container yard space.

Type of equipment	Parallel	Vertical
RTG	Good	Good
Straddle Carrier	Average	Good
Manual ITV	Excellent	Poor
Automated ITV	Poor	Excellent
Reachstacker	Average	NA
Empty container handler	Average	Average

Table 0-1 Selection of equipment as per layout

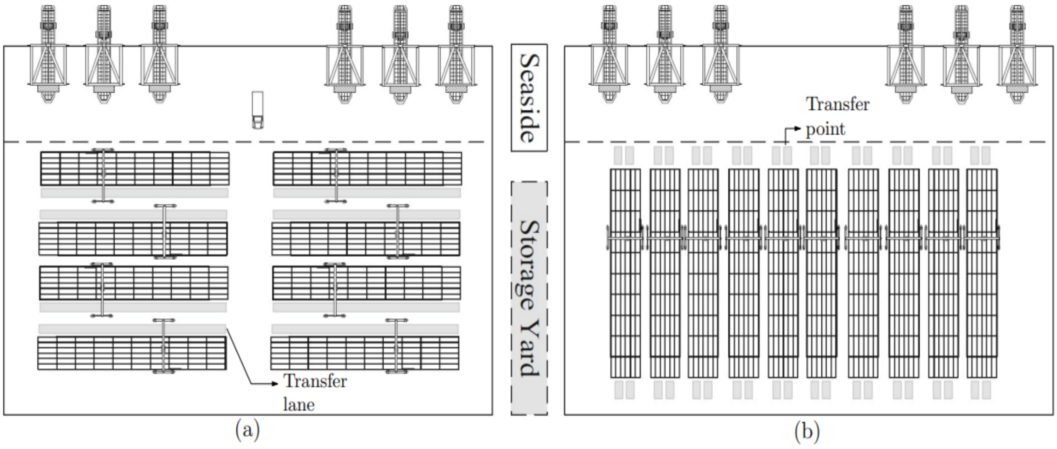


Figure 6 - (a) Parallel layout with transfer lane; (b) Vertical Layout with transfer points

The infrastructure and layout of the container terminals is certainly of the factor that affects the ITV movement. To escape this, the CTOs are changing the winds of the business operation by bringing in the technological disruption such as BOXBAY. This recent development has been in talks of everyone as it is showing the reduction of carbon footprints, aiding the quick handling of the ITV. With time it is expected that container terminals can gain from this by utilising the vertical space (by increasing the stacking height). Although the facts and data for this stays with companies who have invested themselves into it.

b. Terminal Operating Software

The terminal operating software (TOS) is the brain of any container terminal where all the containers are planned to be stored based upon the storage strategy implemented, a location where containers and equipment can be traced, perform planning for vessel discharge /loading. There are several factors the container terminal operators must consider when planning at various levels such as output maximization vs cost reduction, working and analytical power of TOS, workload bearing capacity to do the live tracking of ITV. All TOS are having their own limitations when the container terminals are operating in their peak operational period. Explaining the limitations with an example will be easy to understand. Assume a container terminal that has busy container flow daily and the management levels are always contradicting in their goals when it is time to execute the plans to achieve it. In **Figure 7**, will explain how thinking is carried out at different levels of management.

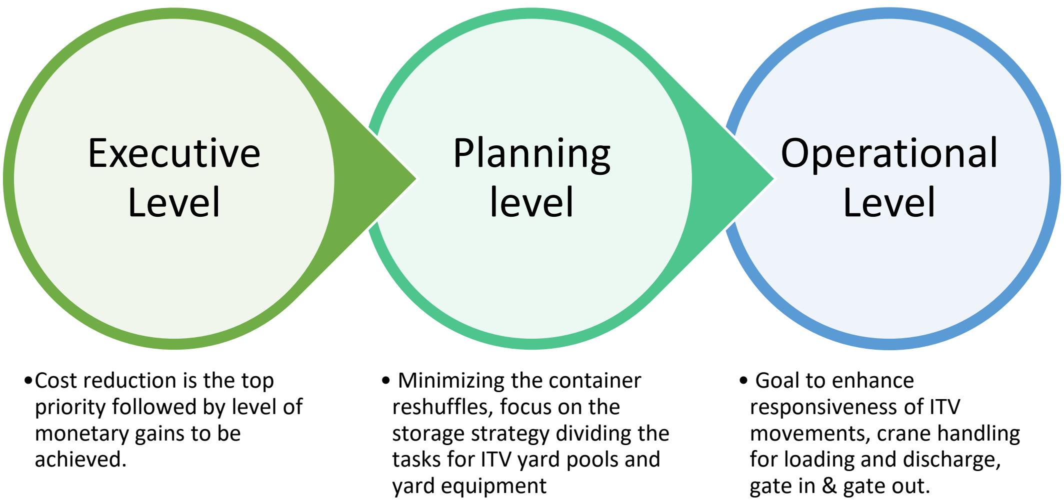


Figure 7 - Goals at different level

If the executive level sets a goal to achieve the cost reduction, then planning and operation levels are having a goal to be responsive in manner. This is the point where a difference lies, and TOS does not understand it. Artificial intelligence in TOS has a long way to reach human understanding and the ability to make decisions. there is a simple rule of nature that says to achieve something, a loss is sure to endure whether small or big. Another example of TOS limitations is the automation of TOS, it is there are blind spots where they cannot process or are not able to make decisions. Most of the container terminals are upgrading their TOS with new functions to manage the complexity, however, even after doing so, the TOS is falling behind. The terminal planners are often using a distribution strategy for managing ITVs by making their yard pools. The continuous dynamic use of the ITVs will ensure that planners do not need to make the yard pools every time a new vessel is berthing on the container terminal. The TOS implemented in the container terminals includes the process for automatic assigning of the ITVs, however, do not bridge the gaps in a real time scenario. The software in the TOS and vehicle mounted terminal (VMT) is different therefore a slight delay in processing, receiving, delivering task within the technical frame exists. To cut these gaps the OEM providers and TOS developers must chalk out plans to according to the discrepancies seen by the operation team. The researcher believes that agent-based technologies can aid the TOS to make decisions and create indications for planners.

c. Yard crane scheduling

A basic linear programming and queuing theory is applied when the yard cranes (RTGs or ASCs) are serving the ITV fleet. The yard crane scheduling for the inter-block movement in a container yard is one of the crucial factors as not every block has one yard crane. A highly, busy container block might have more than one yard crane and in case of automated terminal there are smallest two-yard cranes serving one container block. The ITV fleet must wait when this inter-block movement of yard crane is taking in place which may lead to stop the ITV movement for a couple of minutes. This stoppage cannot be escaped and seen as operational function however, the terminal planners try to limit these processes by the storage strategy. However, an adhoc vessel calling on a terminal might cause this process for certainly. The ITV fleet movement also sometimes creates long queue in the yard or at the pick-up/drop-off point leading to congestions.

d. Storage Strategy and Transshipment

The terminal yard planners have limited space to plan the incoming and outcoming containers volumes in coordination with the gate operators, and shipping line. The terminal layout when viewing in a video or photos looks very simplified just as the Lego blocks, however, are very complex when they are planned through the terminal operating system (TOS). The storage strategies implemented in the terminals are in accordance with number of shipping service, number of inland container depots serving, categories – export/import/transshipment, container classification (IMO class, weight, destination). The terminal planners are adopting the strategies in a dynamic way and this variable does not rely on any other factor. Previously, the terminal planners implemented strategies like FIFO and LIFO however they were ineffective in enhancing the operations. The storage is a basic function of container terminal, and the containers are needed to be stored in a systematic order to avoid any accidental triggers causing explosions among the hazardous cargo or effect winds. (Refer to **Figure 8**)

The terminal planners consider three main points while allocating the designated yard for containers:

1. Stacking height of the container blocks
2. Dwell time of containers
3. Intervals between vessel arrivals

Strategies:

1. Separation strategy: Import containers are separated in the yards while they are planned according to their destinations in the inland. The benefit of this strategy is aiding in the reduction of the reshuffles while retrieval of the old containers. The separation depends on the group code defined by the planning team on basis of the state they intend to be transported by rail or road. The group code is further classified into the destination codes either based on the location of an inland container depot or final consumer destination (in case of major client of terminal).

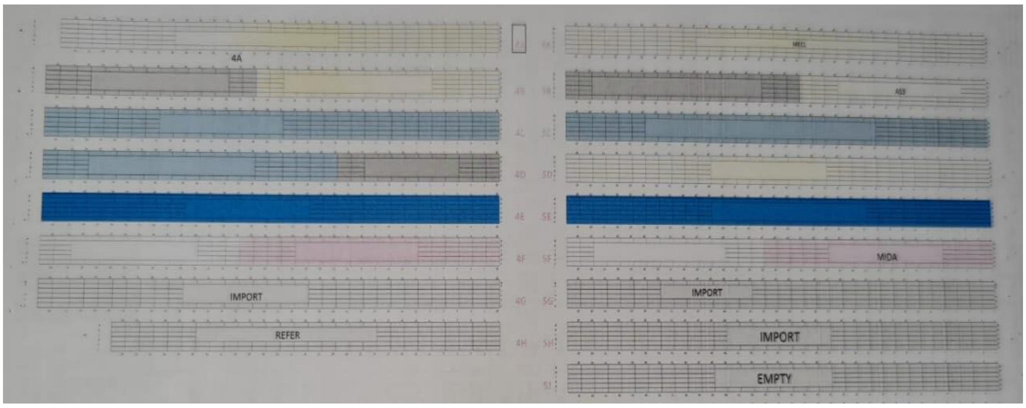


Figure 8 - Sample Storage layout for import containers

2. Clustering strategy - As the name of strategy suggest it is also one kind of grouping however with fine criteria:
    i. Service wise - Based on the shipping services. Container terminals are having several liner services (weekly, bi-weekly) therefore, this is the primary criteria to group the containers.
    ii. Port of destination – The stowage planners of the shipping line are particular in storing the containers in port of destination wise such that next POD containers are stored in the same bay/row/tiers. Therefore, the yard planners in the terminal are making planning for the vessel. The reason is to quick finding, pick-up and drop in the yard or quay area.
    iii. According to the weight – The storage of containers according to their gross weight is necessary as the number of containers which can be stacked on each other is determined by the strength of the corner posts. Therefore, the safety factor is considered. (Refer to **Figure 9**)

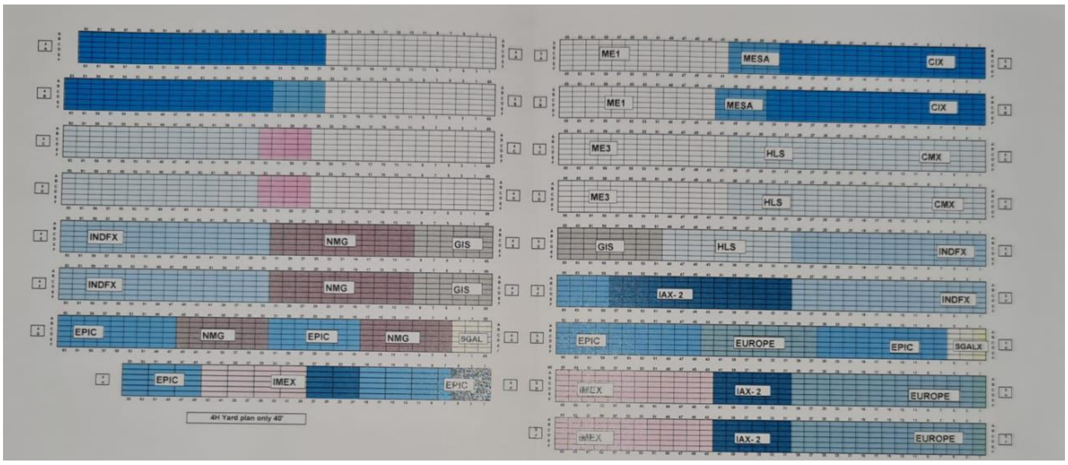


Figure 9 - Sample Storage layout for export containers

3. Consignment strategy – This strategy is implemented for transshipment containers and aid in fast loading process however, this affected the space utilization in the yard. Therefore, space sharing strategy has been implemented with it, to deal the inefficiency when volume of transshipment container is low. When the need of space is low, then same can be allocated to the nearby blocks

having a different strategy. This combining factor always creates a balance in the yard.

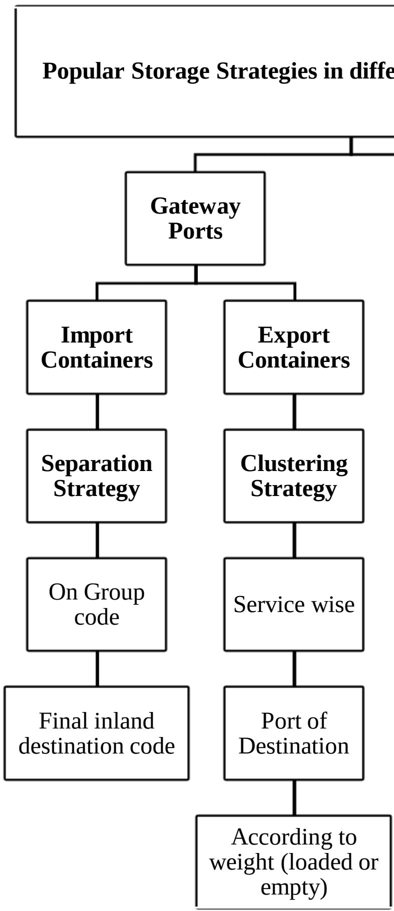


Figure 10 - Storage strategies

The transshipment containers in a container terminal have a small share of affecting the ITV movement. Several major ports which consist of more than one container terminals has seen this challenge as a chunk of ITV fleet is converted into the inter terminal trailers (ITT) working between two container terminals. The transshipment containers picking up and dropping off to the other terminals in the same port is pressurizing the ITV fleet and causing delays. The delays are due to the confusion difference in the exchange policies and different TOS.

It is not like that this situation cannot happen in a single terminal itself, when the transshipment containers are moved within a terminal the ITV must cover long distances to travel up to different container blocks assigned as per the implemented strategy.

e. **Customs and Dwell Time**

The ITV movement in a container terminal is unlikely to be affected by the customs and dwell time. The customs in a container terminal are performing a monitoring the trade activities and collecting the duties on the export or import. The inspection of containers, busting out illegal container loads is the only time when ITV movement is dropped. Over the past few years, the impact of customs is to null. However, the researcher chooses to gather opinion if there are any terminals who considered the customs a variable affecting the yard feeding rate. Container dwell time is nevertheless not yet widely used for purposes of international benchmarking as compared to standard indicators such as productivity indicators or ship turnarounds. Therefore, it is challenging to describe the standard limit above which dwell times would be considered too long in any port. Dwell time should correspond to user perspectives to the "adequate time to enable sufficient importers to clear their cargos according to UNCTAD (2009). However, terminal operators and seaport authorities in practice describe dwelling time according to container traffic trends, profit maximization, capacity constraints, or other considerations for example distinction between domestic and transit commodities. When for example facing high congestion trends, terminal operators and seaport authorities tend to reduce the dwell time. Dwell time in seaports can be assimilated to temporary storage periods as for shippers (exporters and importers) that is justified by the decisions to leave cargos in the ports for a certain number of days or by the time essential to complete formalities of cargo clearance (transactional dwell time). Cargo dwell time is described as the period between container arrival and vessel exit for containerized imports. For most seaports in emerging economies, dwell time exceeds twenty days on average (UNCTAD, 2003). This makes developing nations' seaports most time-inefficient seaports in the globe.

In the global transport chains, container terminals are nothing more than intermodal nodes from a transport service perspective (UNCTAD, 2003). Their basic functions are to transfer effectively used cargo to land transport modes (truck and rails) from maritime transport modes (container ships) and vice-versa. To figure out if it is efficient, we compare the efficiency of the transfer operation to other performance targets such as those related to general berth and yard productivity. We can however just look at the agility at which containers are physically transferred from their containership to the land transport modes through container yards if we specifically concentrate on entry ports' performance for containerized imports (Notteboom 2008). Described as operational stay time, it is the sum of the physical transfer time and the necessary idle time between operations.

The dwell is in fact increasing the housekeeping moves therefore affecting the ITV movement, as many terminals are allowing the landside clients to enter the container terminals for collecting their respective container from the yard. A single mismanagement in the handling and guiding the client TT can lead to disturbing the ITV movement and choking the yard by forming a congestion. In automated terminals a certain number of ITVs (straddle carriers) are assigned to carry-out the receiving/delivering jobs specifically. Therefore, it is necessary to consider the effect while carrying out the data analysis of the same.

f. Quay Crane Productivity

Quay crane operations carry out loading containers from trucks to vessels or unloading containers from vessels to ITVs. The crane operations of these operations are the primary factors that determine container terminal and ITV movement effectiveness and efficiency. Several cranes are arranged to unload or load containers for the vessels when container vessels are moored at berths. The quay cranes are a large steel framework placed on rails along the quay. The researcher considered this as a primary variable affecting the ITV movement as the yard feeding rate is supposed to be equalized. There were times when quay cranes used to be slower compared with the yard feeding rate. Nowadays, the technological advancements in the quay crane and highly skilled nature of the STS/QC have made it opposite, therefore increasing the instances of the quay crane idling as the ITV must travel long distances or increase average waiting time in the container yard. Therefore, terminal planners, top executive and OEM providers are in pursuit to overcome this issue as operational flow is not stable. There are times when ITV movement is affected by the quay crane when the terminals planners initiate the dual cycling or when the unloading operation is about to commence as the average waiting in the quay area is more. Therefore, the researcher has proposed solution to the issue in the further chapter 4.

g. Berth allocation

The berth allocation is assigning the space for vessel berthing. Technically, the berth planners consider the draft specifications, check the call size, and calculate the number of quay cranes needed to serve the vessel. The main motive of perfecting the berthing allocation is to simplify the decrease in berth space usage, minimizing the turnaround times, and emissions. The researcher considers that berth allocation can aid in the minimizing the travel distances for ITV yard pool. Though, this will not be making huge enhancement in the yard feeding however, the ITV assigned for one vessel can operate in specific designated area and lower the travel distance. Taking this opportunity, the terminal planners can improve their internal communications when assigning the vessel, a berth where the most containers are stored in the nearest container blocks.

h. Equipment Breakdown

Container terminals are not an intermodal node where one can see softness while handling the containers with equipment. The equipment breakdowns during the operation time causing instability in the ITV movement, eventually affecting the yard feeding rate. The operational efficiency when reduced due to unforeseen equipment breakdown will require some time to cover the operational backlog if any. The engineering/maintenance teams of the container terminals are implementing the maintenance strategy as per the use of equipment and type of equipment.

2.5 Utilizing agent technology in the TOS

In this section of the research the theoretical background for the qualitative analysis has been discussed and as depicted in the **Figure 11** the researcher is vouching for agent technologies to work aside the terminal operating software. The use of technology and dependence has been growing on a steady rate in terms of commercial purpose. Some technologies are AI powered for their operations and are learning from day-to-day tasks perform by the operator on the machine (PC / mobile) or software (Google assistant). These agents adapt some functions and can perform them individually or on a single touch. They can perform tasks individually by the statistical data they gather whenever the operator completes a task. Currently, there are agent technologies under trials for berth allocation of the vessel to improve the berth productivity and finally increasing the incoming flow vessels in the port as turnround time will enhance. The agent is using berth allocation methods for assigning the incoming vessel which will optimize the berth space and in many cases the ITV movement has minimized with increase in the productivity. In terms of the container terminal, transport agents can be used for simplifications of tasks. Adding more models complex in the system will increase the workload factor on the TOS and on the equipment too.

The primary goal is to use the ITV as ideal as conceivable for designation just as for dispatch of containers. The utility capacity for the transport agent is the level of inhabitancy about the distance to travel. What more can be added in the functions of agent technology is that they can calculate the energy consumption, idle time of ITVs, actual live location of terminal equipment even during the movement taking place and needed maintenance time. The yard planners are occupied with the planning and assigning of containers in the yard. The TOS is not able to find the exact location of every ITV in the terminal. In case the container terminal is worked in traditional way (manual assigning of ITV is needed) resulting in increase of travel distance. In an automatic terminal, the ITVs are assigned automatically in the yard pool however the waiting time is more due to the offset of travelling length.

Another way, to improve the ITV movement is the increase of the transparency between vessel planner (of shipping company) and yard planner. The data sharing of the yard storage plans is no more a secretive way to have an advantage over other competitive terminals. Therefore, the researchers thinks that if this data sharing as per the service is done then container loading/unloading plans, improvising the delivery service of customers (gate operations) are an added benefit to be achieved. The main advantage is that container terminal can coordinate the vessel planner of shipping company, for letting them know about any change in the loading/unloading list. A step can be reduced in the terminal supply chain by terminal planner not boarding the vessel and discussing with the vessel expert or coordinate with the liner company through any communicating platform (email/phone). The liner company and head of the vessel can discuss the loading sequence and evaluate the same internally. The direct effect is on the enhancing the ITV movement in lesser amounts however, every second matters to all the parties involving in it. The terminal planner can improve the ITV flow

In below figure, a sample framework is made on how the agent technology will work therefore increasing productivity and increasing the data sharing transparency.

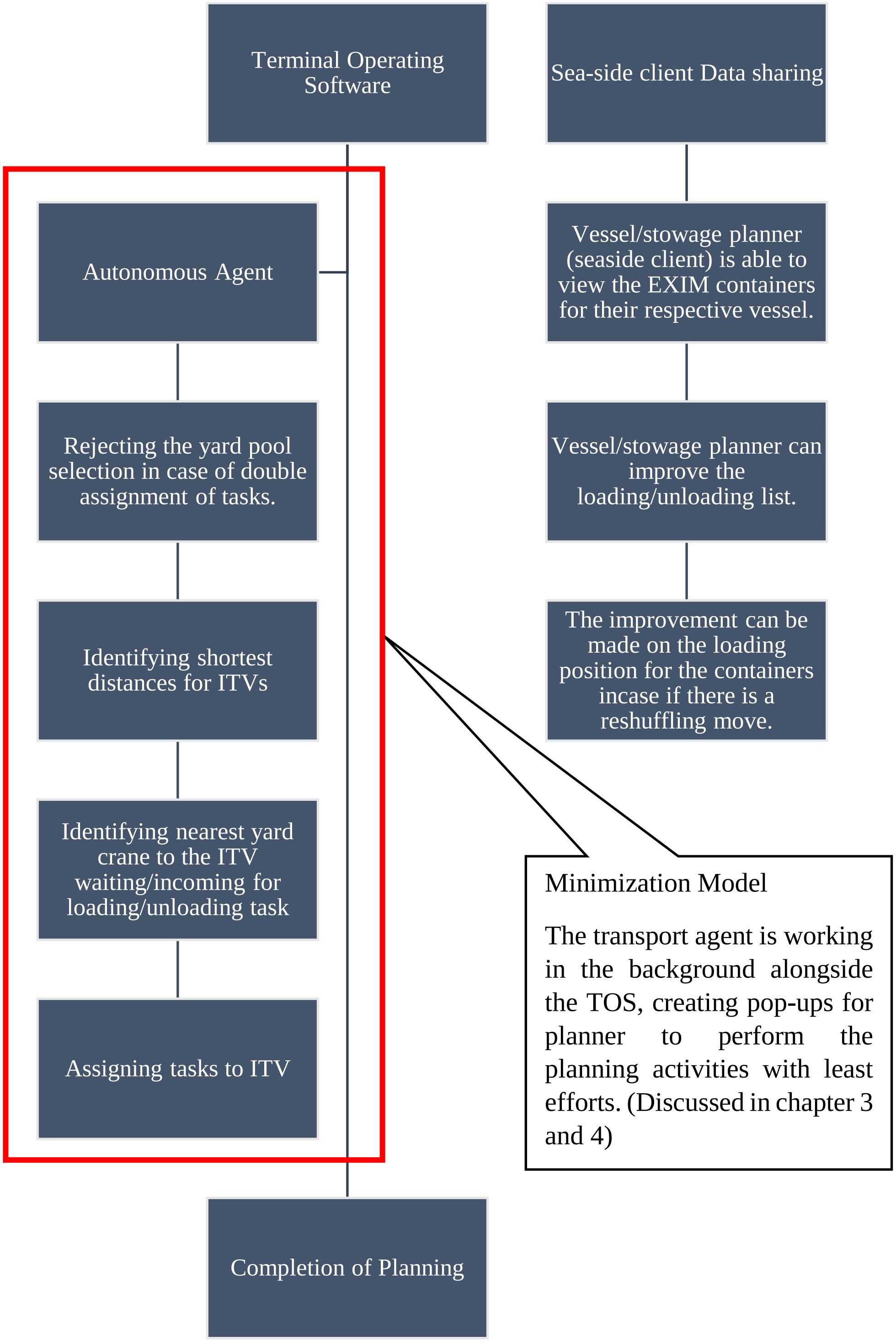


Figure 11 - Figure 11 - Application of agent-based technology

2.5.1 Ideal Situation

The researcher has incorporated a general model for the explaining the minimization model to work in a traditional container terminal. The traditional container terminal is using of the foundational terminal layout which was the parallel layout. This layout has been deployed in most of the terminals, however, several terminal operators have opted both layouts in different regions to find the best layouts applicable. The necessity of considering a general model for this qualitative will aid in application of the minimization model. The distinction of best layout is highly debatable subject; however, the researcher has opted for a parallel layout showed in **Figure 16**. Thus, researcher has quoted it a general layout as it is fit for explaining the ITV movement.

In an ideal situation the difference between real and virtual scenario will be less, as it is expected that TOS should carry out the dynamic use of the ITV fleet. The path identification for whole ITV fleet during continuous operation must be done through a TOS. The synchronization of ITVs vehicle mounted terminal (VMT) software and TOS must be from a same organization or if not then in similar in nature. The TOS developers and terminal planners will understand the need for reducing the gap between real time and virtual scenario. In a real time, scenario, the planning team is always ahead than the operations team for the yard activities, a step-behind means human errors are bound to occur in the daily operations.

2.6 Technological Disruption

Box Bay Technology

The joint venture of DP World and SMS Group (AMOVA) are conducting trials on the boxbay technology by building a high bay storage system (HBS). As a global standard practice containers are stacked on each other, however, the boxbay places containers in an individual rack. This enhanced the stack height upto eleven tiers high and elimination of the re-shuffling moves. AMOVA a subsidiary of the SMS Group was developing this technology and formed JV with DP World group. The readers can relate this technology with the automated warehouses having automated storage – retrieval system (AS/RS) which is only for standard sizes of the consignment (containers). In current scenario the DP World has depicted to use ITVs (straddle carriers) for the yard feeding rate. The boxbay is majorly to address the issues such as terminals that have space constraints, reducing the carbon footprints, etc. The CTOs are keen on learning if it is workable for to deploy this technology in any weather condition and about the maintenance cost. The challenge for many terminal operators is that they depend on the labour force for operations as the geo-political, legal, weather conditions does not seem to be suitable for boxbay.

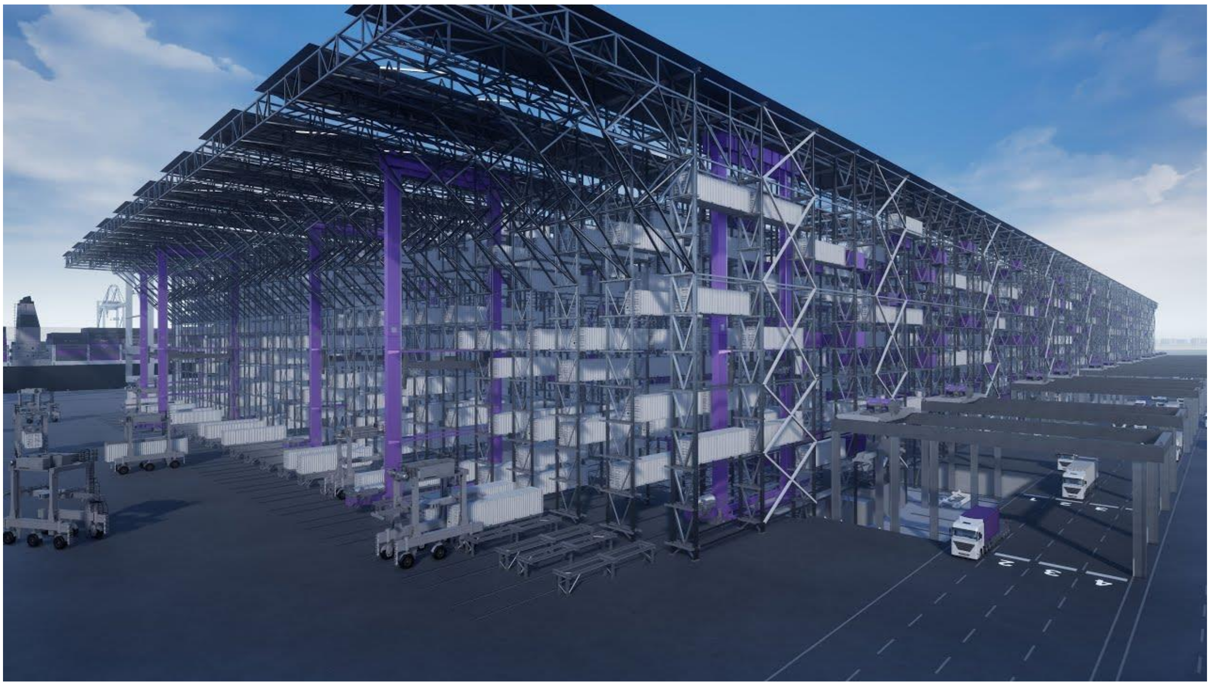


Figure 12 - BOXBAY technology

Advancement in Quay Crane

As quay crane is one of the major equipment and affecting the yard feeding rate (ITV movement) and terminal planners are implementing the twin lifts spreaders plus utilizing the methodologies for achieving the dual cycling to increase the yard feeding rate (minimizing the ITV movement with increase in productivity). The researcher proposes the OEM provider and CTOs to rethink on the quay crane design amidst the upcoming of technological disruption from boxbay or shipping companies for ultra large container ships (ULCS). The current design of the quay crane depends on the ITVs for yard feeding rate and the issue of carbon footprints from ITV is also considered. The research further explains suggesting the change in the main quay crane frame. To see the advancement in the cargo speed is suggesting that transportation by road will be reduced for reducing the traffic and achieving economies of scale through Hyperloop technology.

The CTOs and OEM manufacturers have been working on several plans such as using a "U" design berth where the loading and unloading of vessels can be carried out from the port and starboard side. The researcher argues by saying that the overall impact of changing the design of the berth layout is not a feasible solution to the advancement in quay crane and the each "U" berth will have a fixed quay cranes as the flexibility will be trade-off. The OEM provider

Konecranes has pointed out about the multi-trolley STS crane concept, which is like a yard crane, in this case the yard will be none other than the vessel itself plus multiple trolleys will be deployed. This shows that significant improvement in the berth productivity however, it can increase the structural design of the container terminal depending on the space available.

Figure 13 - Advance Quay Crane. Source - Konecranes

2.7 Summary

The theoretical background is articulating the base of the research which is role and importance of ITV in a container terminal followed by distinguishing the research into two parts. The first part of research is focuses on a quantitative approach by conducting survey and pointing out the relationship between the dependent and independent variables as mentioned above. The necessity of showing the link of this variables via survey will help to find the key issues. Therefore, the researcher has tried to consider every step for yard feeding rate (dependent variable). For the qualitative part of the researcher states about use of agent technology alongside the TOS and improve the data sharing with it. The gap between real and virtual scenario will always create added steps and incur more time. In chapter 3, the research also focuses on the minimization model which can be adopted by the terminal planners or TOS team to simplify their respective case of improving the ITV movement. Lastly, the technological disruptions are discussed as they seem to be in for the researcher’s proposition however not researched due to lack of available data. The proposition made further in the reason is to clearly state that researcher thinks that in future the ITVs will be eliminated as to address the carbon emissions, process improvement, etc.

Chapter 3 - Methodology

3.1 Introduction

Methodologies offer techniques and tools for solving problems. An investigator either has fixed aims and must house the methods for solving the problems and, or has fixed methods such as competence, staff and lab and given the methods, tries to find the optimal objectives. One must try to change both the means and ends at times during the research.

This chapter explains the thesis structure and methodologies used to carry out the data analysis and building the minimization model.

3.2 Research Structure

The research design begins with the introduction stating the main research question and problem statement followed by theoretical background where the role of an ITV, variables considered for the quantitative analysis and the technological disruption. The researcher using two types of methodologies which are as follows:

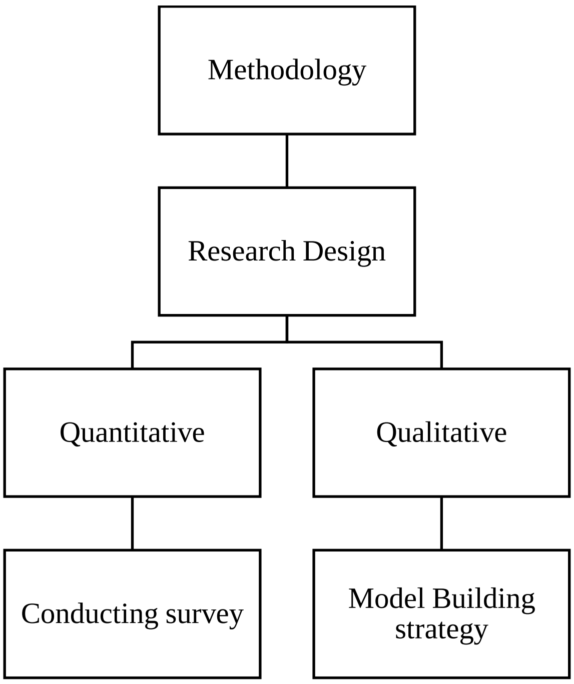


Figure 14 - Research method

Based on the data retrieved from the survey and explaining the model building strategy, it is followed by analysing the data by performing multiple regressions to find the relationship between the variables. As for the minimization model, the rules for deciding the shortest path for ITV is stated to enhance the TOS in a container terminal. Towards the end of research, qualitative suggestions are proposed which are not researched due to early innovative stage and confidentiality reasons.

3.3 Quantitative research

The researcher has opted to conduct his own survey by considering the factors affecting the dependent variable – yard feeding rate. The questionnaire has set of questions focused on slow yard feeding rate and unique nature of this topic is that most terminals focus on their quay cranes, yard cranes to improve the speed however, the yard feeding rate is acting speed limiter on the operation. It will help the terminal operators drive their attention to focus on the root cause for losing the terminal efficiency. Many ports have been conducting internal research about the inter terminal transfers (ITT), such as port of JNPT, Colombo Port, Port of Rotterdam, conducted research in the same. The issue was that terminals in a port must reserve a certain number of respective ITVs from their original fleet to act as ITTs. Hence further improvement in the yard feeding rate was difficult. Port of Rotterdam introduced rail services running between the container terminals under the name of "Port Shuttle," some used barges for the ITT, however ports with complex design and infrastructure had to depend on their personal ITV fleet.

3.3.1 Data Collection for quantitative research

The researcher collected data the primary data for quantitative analysis explained in the chapter 4 has been gathered through by conducting survey. The survey included of detailed questions regarding the personal information, company details, rating for the impact on yard feeding rate with several factors (independent variables). To further investigate the importance of the selected variables for the regression analysis, the researcher reviewed other several research to understand the importance of berth allocation, yard crane scheduling and terminal operating software. A mixed-integer programming model was created to reduce service costs caused by changes in vessels' planned departure times, as well as operational expenses associated with the transit distance of transshipment containers in the yard. Lee et al. (2012) investigated the tactical terminal and yard allocation problem, in which containers move both inside and between terminals. They created an integer programming model to assign a terminal to a vessel and a yard to transshipment containers. Lee and Jin (2013) concentrated on feeder vessel management at transshipment facilities. In contrast to prior research, the feeders' calling schedule was planned from the standpoint of container terminals to alleviate workload congestion. To reduce the overall transport distance of all container flows between the quayside and storage yard, as well as the gap between the peak and lowest workload across the planning horizon, a mixed integer programming model was designed. Jin et al. (2015) reconstructed the problem investigated by Lee and Jin (2013) as a set coverage model. A column generation-based strategy was devised to provide near optimal solutions with similar quality to Lee and Jin's (2013) Memetic heuristic but improved efficiency. Any inefficiency in the berth allocation will have an overall impact on the port congestion, longer travelling for the ITVs in the terminal, and other operational challenges.

The yard operation is the most complicated aspect of a terminal since it handles both inbound and outbound container movements at the same time. The terminal efficiency is heavily influenced by resource planning in the yard. The assignment of storage places to containers (i.e., the grounding policy) and the allocation and scheduling of yard equipment are two distinct study areas connected to yard operation. The amount of burden in each storage block is determined by the grounding policy. Taleb-Ibrahimi et al. (1993) and De Castilho and Daganzo (1993) examined the amount of necessary storage space and the resultant workload for export and import containers under different grounding rules. The yard crane will keep travelling after they complete workload from a container block to the container block with most container flow. Therefore, there performance in the yard also creates an impact on the ITV movement.

The major CTOs have already deployed TOS such as NAVIS SPARCS N4 or higher version, ZODIAC, TBA, OPUS TERMINAL, etc. The choices are varying from organization to organization, and this is also a strategic level decision prior implementation of the TOS on a full-scale level to manage the terminal. The terminal planners must use this as a resource and operate as a brain system by assigning tasks to equipment, ERP, pricing, tracking, cargo capacity. Not all TOS are supplying the complete visibility of the terminal supply chain as the workload on the terminal servers is heavy because of the patch update, third party software integration issues and continuous planning of the containers. The TOS providers across the world are dedicated to improving the output management of TOS and improving the user experience by perfecting the asset utilization.

3.3.2 Selected Variables

The research is focusing on the on the movement of ITV which includes the terminal operating software (TOS), the yard crane scheduling and the berth allocation. The terminal operating software (TOS) is crucial point of a container terminal where all equipment and data related to the clients, costs, storage of containers is being stored in a systematic way. All container terminals across the globe have deployed different versions of TOS however the modus operandi differs from each other. The primary goal of CTOs is to use their TOS efficiently to manage the terminal activities and minimizing the cost. The terminal planners have noticed that yard feeding rate is depending on the TOS performance. The yard crane scheduling is a strong link where the ITV movement can be disturbed when the inter-block movement is taking place in any container terminal. The inter-block movement of any yard crane is occurring on a steady pace in the daily operations because of task completion in a specific container block and to avoid yard crane idling, travelling for breakdown or maintenance, housekeeping moves, etc. In such scenarios, the yard crane scheduling is necessary to avoid long pause on the ITV movement as stopping of the equipment is treated is considered waste. The berth allocation is aiding to achieve the best turnaround time for each vessel and find the ITV movement to be efficient or not. The terminals having their yards placed next to the berth is great to achieve a desired yard feeding rate, however, there are container terminals whose container yards are located away from the berth or quay area.

3.3.3 Rejected independent variables

There are several independent variables which the researcher has not considered for the regression analysis as they are either fixed (meaning it they are not economically viable option to adopt in this industry). It is tempting to include several independent variables as possible, however this could lead to dilution of true goals and lead to large standards errors with imprecise confidence intervals

The container terminals are an investment intensive for which ROI, results can be expected on a slow rate and as the container terminal is a key factor to find the cost effectiveness. On the other hand, the regression model must be significant and fit to be recognized. The rejected variables are not considered for this research however, other researchers or CTO's can include those independent variables for their specific terminals. Even though the independent variables are making an impact on the ITV movement in a container terminal however, the researcher opted to go with the variables having a key role in the yard feeding rate.

Independent variables such as infrastructure, layout, customs, storage strategy, and dwell time are difficult to consider as they are fixed in a solid state or needs higher recognition from top authorities for the rule to bend accordingly. Quay crane moves (Productivity), planner choices and equipment breakdown are unpredictable for maintaining the KPIs of yard feeding rate.

Every container can visualize that quay crane moves is always higher than the yard feeding rate this is due to deployment of several other equipment in the terminal supply chain.

3.3.4 Model for Regression Analysis

The yard feeding is dependent on various independent variables as expressed in the below expression:

$YFR = \beta0 + \beta1x1 + \beta2\ x2 + \beta3\ x3 + \varepsilon$

Where: -

YFR = Dependent variable (Yard Feeding Rate)

B1 x1 = Change in YFR resulting from effect of terminal operating software

$\beta2$ x2 = Change in YFR resulting from effect of yard crane scheduling

$\beta3$ x3 = Change in YFR resulting from effect of berth allocation

$\beta1 - \beta3$ = Regression coefficient for each independent variable

$\beta0$ = Constant or intercept (value of dependent variable when all independent variables are zero)

ε = Random or Stochastic Term.

3.4 Qualitative analyses for Modelling

The second part of the method is based on minimizing the travel distance of the ITV in a container terminal. There are multiple ways to obtain results, however, as the main research question focuses on the agent – based technologies. The sole purpose of the second part of the research is to display how the agent-based technologies should work with the TOS when in use. The researcher has tried to build a minimization model for improving the ITV movement eventually increasing productivity and at the same time achieving efficiency (cost savings, decrease in energy consumption). The MAS will focus to support the decision-making system for terminal operating software. Also, the planners, ITV operators and other equipment operators will be able to work in line with each other. The yard crane scheduling for assigning operations and dynamic allocation of yard pools will be taken care of by the agent technologies.

3.4.1 Data collection for qualitative research

The data gathered for the qualitative part is based on the agent modelling working alongside the TOS. Every container terminal has a TOS which for terminal activities however, the integration lacks a lot when the visibility of TOS cannot supply the real-time data in the terminal. There has been much research for interterminal truck (ITT) route optimization, like vehicle transport movement, vehicle dispatching problems, however, they did not consider the intra terminal vehicle movement. A fleet of ITT is a part of the ITV fleet and in many cases the ITV fleet is running under third party contract, therefore the ITV's VMT are having different software than the main TOS, making the integration difficult. Therefore, many researchers and CTOs believe in adopting innovative technologies for building an information system that allows a real-time data interchange for decision support, stakeholder cooperation, knowledge sharing, and planning process optimization.

3.4.2 Case Study

To prove the application of minimization model in an actual case, the researcher selected an actual port where the minimization model can be applied in the terminals located in the Port of Nhava Sheva. The port of Nhava Sheva is in India on the western coastline and serving sizeable amount of EXIM trade. This port consist of four major terminal operators – APM Terminals, DP World, JNPCT and PSA. The researcher prefers to discuss an intriguing case of DP World CTO who is currently running two terminals namely Nhava Sheva International Container Terminal (NSICT) and Nhava Sheva International Gateway Terminal (NSIGT). The terminals have appointed third party for making up for the ITV fleet and due to odd layout, the terminal has been facing with slow yard feeding issue. Another point to note for them is that both terminals are having different TOS systems as they already have the resource and legally it is not possible to treat them as a single entity. The terminal planners of both terminals have been using the ITV in a joint fashion, however, due to lack of TOS integration the ITVs are assigned with multiple task assignment. A dynamic use of the ITV fleet creates bottlenecks and the software installed in the VMTs of ITVs is different from the main TOS of both terminals. Therefore, task processing and integration is difficult. The ITV tracking monitor cannot show the real time position of the ITV to the yard planner, as there is lacking in the real-time data versus the virtual-time data. Sharing of the ITV fleet between two terminals is complex way to deal the situation for slow yard feeding rate.

3.4.3 Agent-Based Modelling

The deployment of agents provides a new way of comprehending and solving challenges that are found in the container terminal domains. The models become multi-agent simulations (MAS) by having more than one agent that results in more complicated issues, such as how the agent work together or communicate to meet the goals and activities. In this area, the developments have resulted in several agent-based technologies like multi-agent-based simulations (MABS).

Multi-agent-based simulations/models differ from other types of computer-oriented simulations in that some of the simulated organizations are simulated and executed in terms of agents. As multi-agent-oriented models and other micro-modelling methods clearly try to simulate individual behaviours, they can be contrasted to macro-modelling methods that basically founded on mathematical simulations in which population characteristics are averaged together the simulation tries to model modifications in the averaged properties for the entire group. Therefore, while in micro-simulation the structures are seen as emergent from the interactions among the individuals, the set of individuals is seen as a structure in macro-simulations that several variables can characterize. The micro-simulation and micro-simulation approaches have been compared by Parunak et al. (1998). Parunak et al. (1998) also noted their comparative advantages and disadvantages. Parunak et al. (1998) noted that agent-oriented simulations are most relevant for domains dominated by discrete decisions and characterized by a higher level of distribution and localization.

The researcher suggests that a transport agent having a minimization model running alongside the TOS of both terminals can save time for ITV distribution with set parameters for the yard pool assigning. This set of parameters can be planned by the terminal planners so they can coordinate the ITV fleet whenever vessels are berthed on any of the terminals. The **Figure 15**, shows that the travelling distance for ITVs in NSIGT is higher than NSICT. Therefore, the necessity of minimizing the travel distance for ITV is important and leading to cost saving for fuel and reducing the yard congestion during the inter-block movement for a yard crane.

Figure 15 - Aerial view of NSICT (in red) and NSIGT (in white)

3.4.4 Model Building strategy

The researcher used computer programs like excel and google earth to understand the terminal layouts and specifications using the 3D tool available. This helped to decide the variables to be used in the model

- travel speed and time of ITV
- Waiting time of ITV
- Operational speed and time of yard equipment

This part of research focuses on the transport agent aiding the ITVs for a minimal movement with more output which means the distance of travelling can be minimized by achieving a dual cycling both in quay and yard area. In case, the transport agent can be deployed and have the flexibility of assigning yard pools as per the real time location of a specific ITV. The retrieval and stacking of containers should be enhanced by the parabolic transition of the yard cranes spreaders with keeping in mind the hoisting speed. In this research the minimization model is based on a general layout shown in the **Figure 16**. Though the container terminals also use a vertical layout which is adopted by the terminals having automation as their kingpin goal to achieve due to several factors such as modern technologies, methods for carrying out operations. The researcher is keen with a parallel layout for simple understanding and due to insufficient data available on the automation techniques, it is difficult to show. The general layout is best fit for this research as discussed in the section 2.5.1.

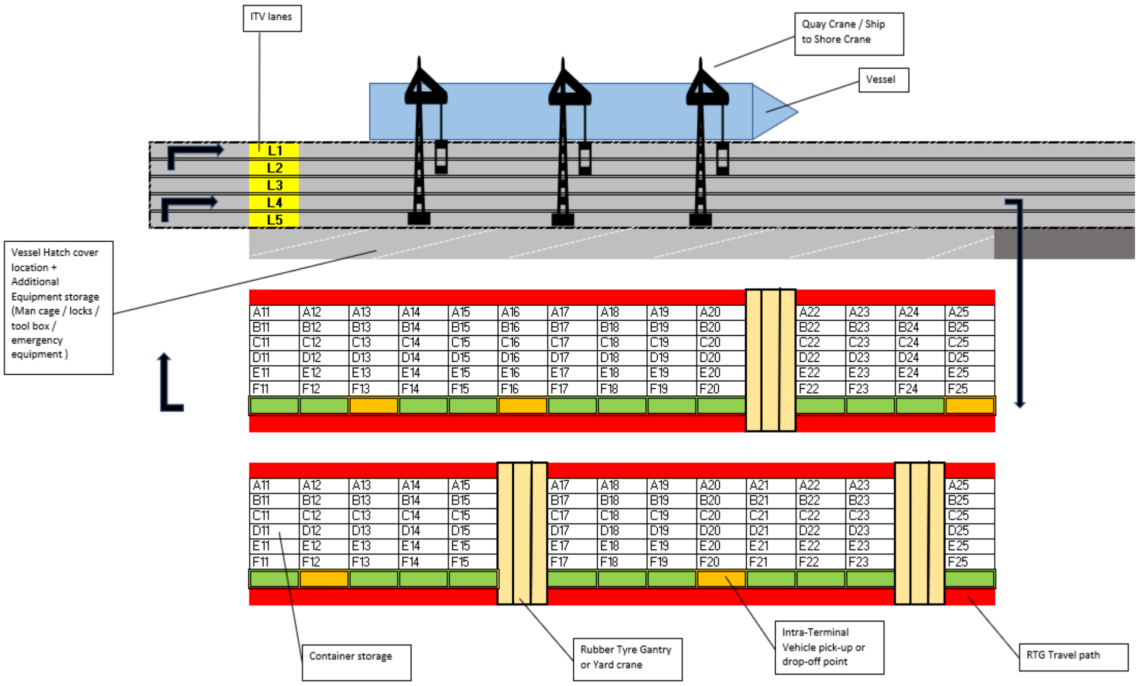


Figure 16 - General layout of a container terminal

The motivation for such model building came into existence after understanding the software like Google maps or vehicle routing programs used by parcel companies. Therefore, the researcher has tried their best to build a general model base that can be used for any terminal layout. The agents can function such that they understand the goals to be achieved. In **Figure 16**, it depicts a general layout of a container terminal (parallel) where the containers ae stacked in a parallel direction with the quay. The yard cranes operating speed for travelling, speed hoisting the trolley and the choosing of the maximum workload container block position can reduce the movement of yard crane. In a container terminal, yard crane scheduling is must to avoid the further complications as the vessels call size differs every time, therefore a pre-planning of the yard crane movement should be predicted according to the loading and unloading list. The terminal planner is playing a crucial role in the yard pooling for the tasks and using the ITV fleet in a dynamic way. As discussed previously, that container terminals are like an ant colony and complex in structure. Therefore, the movement of ants can cause a misdirection in some cases and thus real time visibility of the transport agent in case of ants is special secretive they leave behind when they are the last to notify other ants for shorter roue they travelled. Similarly, the container terminals must be installed with an agent technology in their ITV fleet, or they must consider incorporating a similar framework in their TOS for synchronizing the yard pooling of the ITV fleet.

3.5 Summary

This chapter provided details of the study's method and procedures. This research aimed to explore how the movement of the intra terminal vehicle could enhance in the container terminals. In the quantitative study focuses on the conducting of survey based on the variables described in the chapter 2. The qualitative study followed by designing a minimization model to examine how the movement of the intra terminal vehicle could enhance in the container terminals. The researcher selected terminals situated in India, namely – NSIGT and NSICT, additionally suggesting for adopting agent technologies for synchronizing the activities. The further study incorporated into the data presentation of survey, including a demographics questionnaire and a minimization model.

Chapter 4 – Data Presentation & Findings

4.0 Introduction

According to the research method explained above, this chapter presents the data presentation and analysis (Kumar, 2018). It has a comprehensive summary of the key findings from the survey responses for the analysing several factors playing role in affecting ITV movements. This chapter outlined data presentations, analyses, and interpretations. The respondents' demographic characteristics and data obtained from the survey is presented and interpreted. Also, includes the presentation for the minimization model for a container terminal to reduce the movement while improving the productivity. The thematic and content analyses are used to analyse the data collected. The chapter 4 is stating the data presentation and findings for the quantitative and qualitative research.

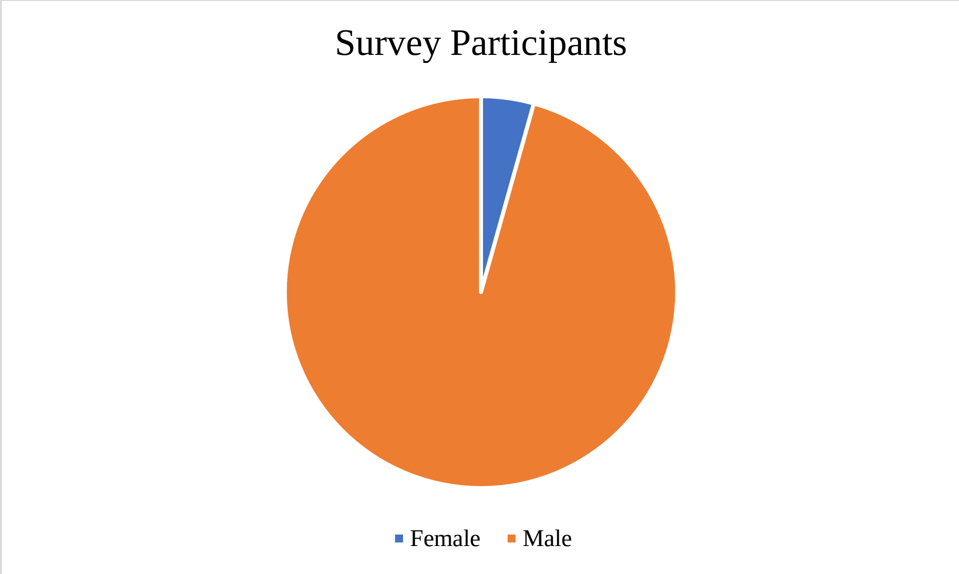
4.1 Respondent's data for quantitative research

This part explains the frequency distributions of the demographic and personal features of the survey participants. Therefore, demographic traits such as job profiles, terminal location and gender are presented using percentages and frequencies. The audience group is working on/with the daily tasks/challenges faced while in the operation of ITV management. ITV management is a complex procedure however, sometimes becoming a reason to decrease the operational performance. In virtual interface, the operational activity is smooth and scheduled however if compared with the ground reality, the situations are different. The mix group of audience will aid in building a concrete base for the thesis; therefore, the questionnaire is direct and to the point. The form was kept open to global and not focusing on continental as each terminal is different with unique TOS, several types of ITV, etc.

Target Audience	Department	Relation
Terminal Operator	Operation	Core
Yard Planner	Operation	Core
TOS operator or developer	IT	Core
Crane Operator	Operation	Core
ITV (Truck) Operators	Operation	Core
Shipping Line	Planning	Core
Berth Planner	Operation	Core
Maintenance manager	Engineering	Core
Academicians/Researchers	Educational	Indirect
Port Authority	NA	Indirect
Terminal Designer or OEM	Manufacturing	Core

Table 0-1 Target Audience for Survey

The target audience was approached via the LinkedIn platform to cut the chase and gather data with the help of google forms.



Graph 1 - Survey Participants stating gender

The survey was responded by twenty-three people from different terminals all round the world and it is concluded that most of the respondents were male. The respondents are currently collaborating with companies like APM terminals, DP World, Adani Ports, Liebherr, etc from the working regions of India, Morocco, Sri Lanka, Egypt, Pakistan, Nigeria, Peru, UAE, etc. The diverse group help to analyse the work environment and the type of thinking is done when they are dealing with peak seasons. The researcher has also worked in container terminals and had a prior knowledge of TOS functions.

4.2 Data Findings and Analysis

The researcher used MS-excel for analysing the gathered data from the survey. From the data, a correlation table generated to understand the relationship between dependent and independent variable.

Based on correlation analysis, the researcher removed the independent variables which were not fit for the multiple regression model. The three independent variables berth allocation, yard crane scheduling and TOS were showed to be more dependable for this research. The importance of berth allocation is the average waiting time for ITV in the quay area which is 4 minutes 48 seconds this is leading to the ITV idling and treated as waste. The same is applied when the average waiting time for ITV in container yard is 8 minutes 17 seconds which is exceedingly high and can be presumed the container yard is running full, making too many housekeeping moves, or overburdened with a schedule of tasks. In a TOS, 65.21% respondents checked the box for "Yes" – to have an automatic assigning of tasks to the ITVs. If this is possible, then the CTO's can be sure that they can rely on their TOS for providing an optimal solution and increasing the focus of employee on the core activities. In peak operational hours, the human brain is working under pressure and thus a supporting from TOS will enhance the performance.

	slow yard feeding rate	*Infrastructure*	*Layout*	*Storage strategy*	*Transshipment*	*Quay Crane moves*	*Berth allocation*	*Yard crane scheduling*	*TOS*	*Planner/Operator*	*Customs*	*Equipment Breakdown*	*Dwell time*
slow yard feeding rate	**1**												
Infrastructure	0.159	**1**											
Layout	0.219	0.187	**1**										
Storage strategy	0.216	0.567	0.438	**1**									
Transshipment	0.146	0.198	0.230	0.264	**1**								
Quay Crane moves	-0.007	0.589	0.143	0.228	0.395	**1**							
Berth allocation	0.291	0.523	0.162	0.361	0.139	0.447	**1**						
Yard crane scheduling	0.057	0.735	0.137	0.426	0.320	0.634	0.642	**1**					
TOS	0.312	0.310	0.015	0.251	0.285	0.461	0.458	0.637	**1**				
Planner/Operator	0.091	0.589	-0.035	0.514	0.044	0.465	0.526	0.706	0.669	**1**			
Customs	-0.166	-0.003	0.085	0.227	0.232	0.240	0.300	0.319	0.290	0.420	**1**		
Equipment Breakdown	0.107	0.319	-0.026	0.242	0.108	0.353	0.397	0.494	0.426	0.644	0.544	**1**	
Dwell time	0.118	0.361	-0.228	0.211	0.424	0.215	0.340	0.384	0.387	0.407	0.488	0.380	**1**

Table 0-2 Correlation table

4.2.1 Model Summary

The researcher conducted multiple regression analysis with the aid of the MS-Excel to form a significant result from the calculation. As the research is keeping it is focus on the yard feeding rate (YFR) thus the main independent variables account for them are the berth allocation, yard crane scheduling, and TOS. In a container terminal the changing any fixed elements such as adopting a new layout or storage strategy is a big-budget discussion and time taken to achieve the return on investment from the capital finance is going to be slow. Every organisation is keen on improving their business process followed by a streamlining in their respective supply chain which is better than implementing on a big strategic level decision. A continuous improvement in managing the container flow in the container terminal is beneficial.

In the below **Table 0-4**, the multiple regression analysis conducted was included all the independent variables to analyse the relationship of a dependent variable and other several independent variables. The gain from this method aided in the predicting outcomes for based on the manipulation of a variable at a time. The 47.2% combination of all variables shows an impact on the yard feeding rate. The higher number of variables will only lead to complex structure and can state drive a focus to the variables which are non-significant in nature. The independent variables may have been a considerable influence on the yard feeding rate, this do not imply to overlook on the variables having an effect from the financial or engineering point of view.

Regression Statistics	
Multiple R	0.687
R Square	0.472
Adjusted R Square	-0.163
Standard Error	0.214
Observations	23

Table 0-3 Initial Regression Statistics

The researcher was keen on the independent variables having a larger p-value and rejecting them by performing them in a systematic manner.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.139	0.269	-0.516	0.617
Infrastructure	0.026	0.062	0.411	0.690
Layout	0.013	0.022	0.592	0.567
Storage strategy	0.009	0.040	0.226	0.825
Transshipment	0.009	0.027	0.323	0.753
Quay Crane moves	-0.021	0.034	-0.620	0.549
Berth allocation	0.041	0.034	1.213	0.253
Yard crane scheduling	-0.060	0.054	-1.123	0.288
TOS	0.052	0.037	1.413	0.188
Planner/Operator	-0.028	0.062	-0.451	0.661
Customs	-0.025	0.031	-0.802	0.441
Equipment Breakdown	0.027	0.031	0.874	0.403
Dwell time	0.007	0.038	0.182	0.859

Table 0-4 Initial table for regression coefficient (Highlighted are the selected independent variables)

As said in the chapter 3, for selecting and rejecting the variables for the final multiple regression analysis is to keep the model significant and the focus is solely to analyse the main three independent variables – berth allocation, yard crane scheduling and TOS. The researcher performed several regression analyses for the rejected variables. The aim of the container terminal is to ensure a high terminal throughput from there yard to the berth by TOS operation.

From the multiple regression analysis which was conducted for this research states that R – square 0.223 i.e., 22.3% of the combinations of variables – berth allocation, yard crane scheduling and terminal operating software the impact on the ITV movement. The berth allocation in recent times have improved due to increased real time visibility of the berthing allocation method. However, yard crane scheduling which refers to the movement of yard crane while deployed for yard feeding and the YC inter-block movement is needed to be efficient. The VMT in ITV and the real time visibility for viewing the container location is having a gap to connect with the TOS due to several complexity of commands, codes in the software.

Regression Statistics	
Multiple R	0.472
R Square	0.223
Adjusted R Square	0.100
Standard Error	0.188
Observations	23

Table 0-5 Final table for regression statistics

4.2.2 Regression Coefficient

The size of the coefficient for every independent variable in simple or multiple linear regression reflects the extent of the influence that variable has on your dependent variable (yard feeding rate), and the correlation coefficient value (positive or negative) says the direction of the effect. Th researcher performed several multiple regression analyses to highlight the main independent variables making an impact on the yard feeding rate. As mentioned in the section 3.3.3, the rejected independent variables were insignificant and thus not fit for this model. In **Table 0-6**, the rejected variables are shown and as they have a high p-value. The researcher found them insignificant.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
	P-value	*P-value*	*P-value*	*P-value*	*P-value*	*P-value*	*P-value*	*P-value*	*P-value*	*P-value*
Independent variables										
Infrastructure	0.690	0.481	0.384	0.441	Rejected					
Layout	0.567	0.555	0.414	0.349	0.291	0.294	0.218	0.256	0.296	Rejected
Storage strategy	0.825	0.846	Rejected							
Transshipment	0.753	0.611	0.527	0.370	0.377	0.475	Rejected			
Quay Crane moves	0.549	0.408	0.325	0.328	0.422	Rejected				
Berth allocation	0.253	0.214	0.191	0.169	0.128	0.137	0.151	0.131	0.184	0.151
Yard crane scheduling	0.288	0.202	0.163	0.145	0.195	0.093	0.108	0.139	0.118	0.139
TOS	0.188	0.118	0.105	0.086	0.109	0.112	0.085	0.067	0.098	0.118

Planner/Operator	0.661	0.630	0.645	Rejected					
Customs	0.441	0.364	0.352	0.224	0.094	0.094	0.107	0.159	Rejected
Equipment Breakdown	0.403	0.383	0.373	0.414	0.333	0.354	0.390	Rejected	
Dwell time	0.859	Rejected	0.000						

Table 0-6 - Rejected Independent variables

Since there are three independent variables in the final regression analysis, the coefficient tells how much the yard feeding rate is predicted to grow when that independent variable rises by one while the other independent variables still are constant. In **Table 0-7**, three independent variables – berth allocation, yard crane scheduling and TOS are significant

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.018	0.186	-0.095	0.925
Berth allocation	0.043	0.028	1.498	0.151
Yard crane scheduling	-0.046	0.030	-1.545	0.139
TOS	0.037	0.022	1.636	0.118

Table 0-7 Final table for regression coefficient

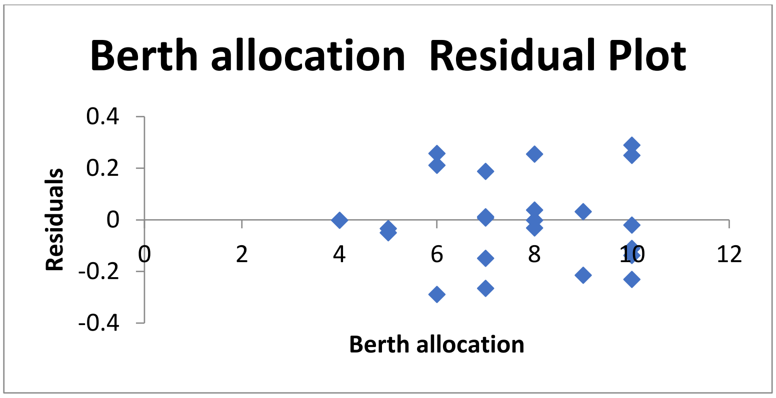
$$\mathbf{YFR = -\ 0.018 + 0.043\ x1 + (-0.046\ x2) + 0.037\ x3 + \varepsilon}$$

4.2.3 Model Validation

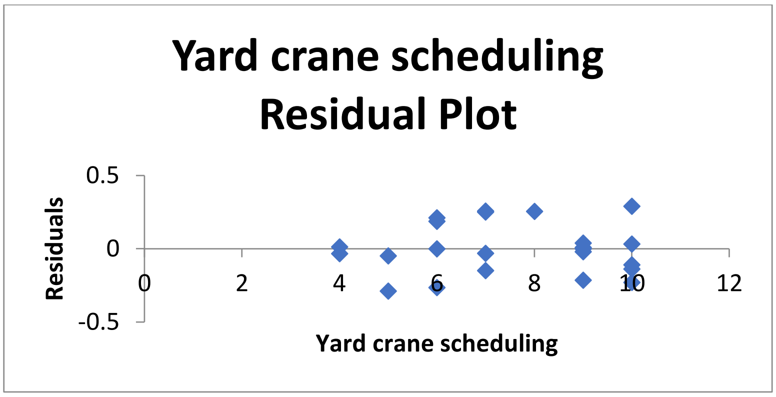
A residual is a measure of how distant a point is from the regression line vertically. The residual values are on the Y-axis, while the independent variable is on the x-axis in a typical residual plot. We can never predict something perfectly, every regression model has some degree of error. More crucially, unpredictability and randomness are always present in the regression model.

Response = Deterministic element + stochastic element

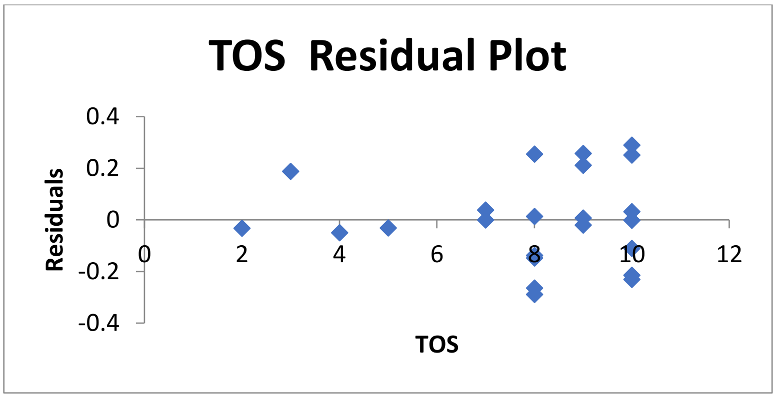
The regression model tries to stand for the deterministic element of the model. If we capture all the predicted information, anything that stays (residuals) should be fully random and unpredictable, i.e., stochastic. As a result, we want our residuals to have a normal distribution. The below residual plot for the three selected independent variables is shown below:



Graph 2 Residual plot for berth allocation



Graph 3 Residual plot for yard crane scheduling



Graph 4 Residual plot for TOS

Validate the regression models, residual plots must be used to visually prove the model's validity. Because plotting all residual values across all independent variables can be a little difficult, the researcher chose to make different plots in this situation.

4.3 Qualitative data presentation - Minimization Model

The final output of this model will be worked by the agent technology and the information will be passed on to the TOS and terminal planners. This will aid in minimizing the travel distance of ITVs following an improvement in the yard feeding rate. The quay crane / Ship to Shore crane operators sometimes is highly skilled during which the loading and discharge speed does not match the yard feeding rate. If these two KPI's are not matched, then the terminal loses efficiency and responsiveness. Terminal planners are dealing with this situation multiple times in daily operations, however, complex storage strategies are used for the smooth running of a terminal. The multiple regression analysis focuses more on the overall efficiency where this model is answering the operational side of handling ITV and providing a framework of how agent-based technologies will function in line with TOS. In Figure 6, the container yard block near the quay apron has an only a one-yard crane with three ITV's waiting for either container loading or unloading or double cycling from its trailer chassis. Let us assume for now a transport agent technology is being used alongside the TOS, then it will find the positions of ITVs and Yard cranes where they are found. Followed by calculating the speed and time needed for the tasks and will show to the planner that a specific ITV is near to a yard crane. This will help the yard planner to assign the task manually or automatically whichever case is applicable depending on the nature of the agent. The agent technology used is reducing the travel distance of ITV's and making smart decisions to perform the tasks. The parabolic transition of the yard crane's spreader speed and angle must be as small as possible to save some seconds in the operating time. Many equipment drivers have known this technique however in case of remote-controlled equipment it is difficult to follow such technique. As the virtual view is widely differed in comparison with the real top view from a cabin of the operator. This will lead to an increase in the yard feeding rate.

Notations used in the model:

D_i = Travelling distance for ITV

s_i = speed of ITV

t_i = time taken for ITV from one point to another

D_{yc} = Travelling distance for Yard crane

s_{yc} = speed of yard crane

t_{yc} = time taken for yard crane from one point to another

w_i = waiting time of ITV

o_{yc} = operating speed of yard crane

D_o = Operating distance of Yard crane at the time of carrying out tasks

Ɛ = error constant

Using the three important variables of physics, we

$$D_i = s_i * t_i \text{ ………eq. 1}$$

$$D_{yc} = s_{yc} * t_{yc} \text{ ………eq. 2}$$

$$D_o = o_{yc} * w_i \text{ ………eq. 3}$$

From the addition of eq. 1, 2 and 3 we get and applying the minimize function,

$$\text{Minimize } [D_i + D_{yc} + D_o + \varepsilon]$$

The o_{yc} can be improved with having a smart parabolic transition (while hoisting of the containers from the ITV and stacking the same in a container block. When a container is lifted from the ITV chassis or from a stack of containers through the spreader of the yard crane in a straight line. It is not necessary that the straight line is always the fastest path. While descending of the trolley, the research suggests about the curve of fastest decent also known as the "Brachistochrone curve." In mathematical terms, one can refer to the calculus of variations that uses variations, or slight changes in functions and functionals, to figure out functional maxima and minima: mappings from a collection of functions to real numbers. The definite integrals of functions and their derivatives are widely used to define functionals.

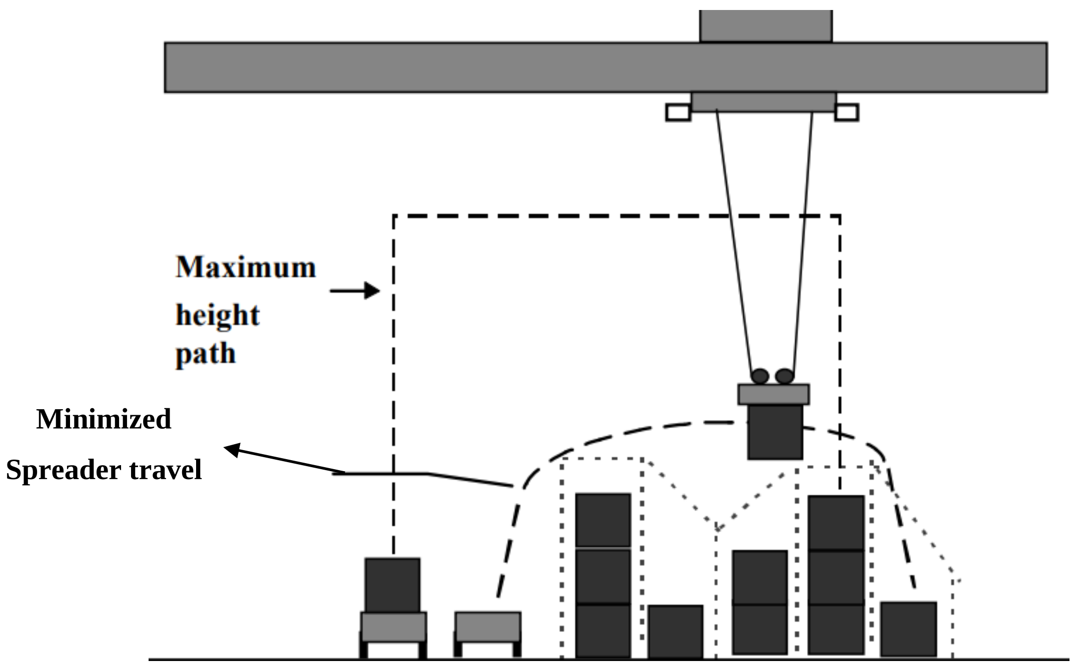


Figure 17 - Best path for spreader

Enhance the D_{yc} CTOs must consider forming a SOP for the yard crane operators by managing the container block having most workload and distributing the ITV yard pool accordingly. The yard crane scheduling will play a crucial role where the inter-block movement of yard crane can be minimized therefore increasing the yard feeding output. An involvement of the terminal planners and stowage planner on mutual basis will ease up in forming the loading and unloading sequence from a vessel. In short, two points the terminals should look out for a smart SOP for their yard crane operators and a data transparency with the clients.

The multi-agent technologies could be used to perform the extra tasks of terminal planners and equipment operators. For example, the ITVs are installed with vehicle-mounted terminals showing the operator task assigned to it, however, MAS can aid in choosing the best task for the operator. In case of an automated guided vehicle, the issue of assigning should solve with help of this minimization model installed in the software. As the world is moving towards automation, the expectations of maritime professionals are increasing in the regard for deploying AGV in future. In cases, it is seen that automated terminals are having a shortage of equipment compared to the quay length.

4.3.1 Application of minimization model in actual case

On comparing the two container terminals in the Nhava Sheva with the idealistic situation differs, as there TOS is not a single stop solution as the TOS of both terminals depends on the third-party software to perform at par with the standards. Legally, the terminal cannot share the space between both terminals, i.e., changing a layout, however, they can surely merge their TOS in one (refer **Figure 18**). The researcher is citing to incorporate a transport agent which can be installed in the VMT's of ITV fleet and running with TOS for aiding the planner. Both NSICT and NSIGT are run by DP World which can internally discuss and sought the challenge of improving yard feeding rate. The installation new programming in the VMTs of ITV fleet is much economical than adding a package in the TOS is time consuming procedure for the TOS developer and implementation team.

The minimization model running alongside the TOS will improve the performance as the output management for TOS will reduce significantly. The testing on full scale is risky and losing valuable time. The agent technologies are promising for future as the world is adapting the artificial intelligence and machine learning languages concepts. For example, there are OEM providers who are already researching in an automated container handling equipment (CHE) which are including of agent technologies.

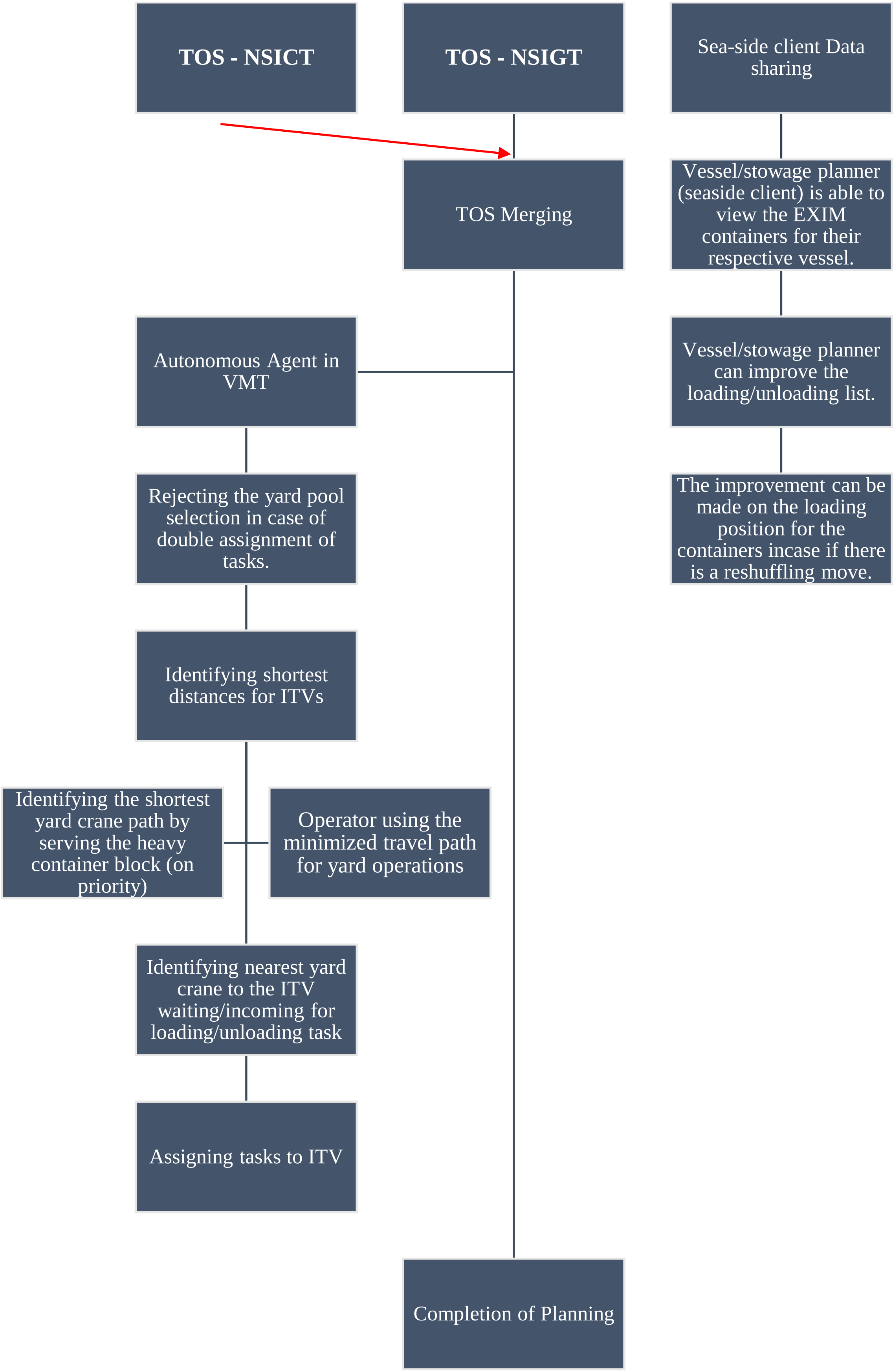


Figure 18 - Application of minimization model in actual case

4.4 Summary

This chapter presented data and findings for both quantitative and qualitative research. In quantitative data findings and research, several independent variables were rejected based on multiple regression performed. The analysis showed that ignoring those variables will be best suited for the regression model. In the second part for qualitative research findings, a minimization model was formed and then applied to the actual case of DP World terminals - NSICT & NSIGT. The comparison of these two terminals is best suited and intriguing for process improvement in relation to the ideal situation. Bringing an ideal situation to reality is difficult impossible in many cases. The minimization model gives a straight win for the terminals with in lower monetary investment.

Chapter 5 – Conclusion

The main research question - How can container terminals improve the intra-terminal vehicle movement? The research answers the main research question by finding the most significant independent variables, making an impact on the yard feeding rate in the quantitative findings and the CTO's can adopt agent technologies for improving the ITV movement (by minimizing the distance travelled with increased output). The conclusion is that CTOs needs to focus on the variables affecting the ITV movement which are berth allocation, yard crane scheduling and TOS. The researcher initially chose all the independent variables affecting the ITV movement however, after performing the regression analysis it was found that it is best to reject some independent variables. While summarizing the quantitative research, it is suggested to the CTO's that they should improve the yard crane scheduling process so that the yard crane has a minimal movement for inter-block movement. To back up the yard crane scheduling, the terminal planners should think to increase the transparency for data sharing of the storage strategy for their clients individually. The data transparency can also lead to improvising in the stowage planning process for their clients. The end results can be such that a whole service turnaround time can be improved by enhancing the ITV movement. The terminal planners can achieve dual cycling at the earliest when a vessel operation is started if a pre-planning and coordination of the same is conducted with their clients. A continuous business improvement in the TOS and berth allocation with respect to yard crane scheduling will enhance the yard feeding rate. Additionally, the experiences of defining, exploring, and discussing the applications of three selected variables in container terminals have produced ideas for future studies. The equation of multiple regression will be **YFR = - 0.018 + 0.043 x1 + (-0.046 x2) + 0.037 x3 + ε** giving the relationship that exists between sets of data.

The minimization model covered in the research is based on physics fundamentals and no rocket science to be applied. The minimization model applied in research serves a proof that agent technologies are useful for the decision-making analysis and achieving the set goals. The researcher concluded that transport agents are suitable to use to solve the problems of yard feeding rate and improving the ITV movement in the container terminal. An autonomous agent can help to reduce the workload as well as dynamic use of ITVs will lead to efficient management. The ITV movement developments have offered experience in trying to simulate and model complex systems for container terminal management. The first approach of modelling the entire container terminal systems proved to be quite challenged, therefore the method of modelling the container terminal prove to be more manageable. In designing future decision support systems for container terminal executives, ITV movement is but a single method that shall be supported with added container terminal models.

5.1 Qualitative Discussion

Further the researcher is proposing ways to improve the ITV movement. The CTOs can rethink their strategy where they can adopt the techniques as per the suitable scenario.

1. **By lowering the quay crane productivity**

   Not lowering quay crane productivity, is not workable for transshipment terminals because it's mainly about the quay performance to respect the berthing prospects to avoid any possible congestion outside the port. Commercially the effect will be loss of clients as the shipping lines prefers terminal partners with high crane productivity as the vessel turnaround time is reduced. The researcher states that this alternative is on the very less likely to be implemented just for improving the ITV movement. The possibility of implementing this method is only in the time of any emergency due to lack of manpower in the terminal, or to reduce the yard congestion. However, this only to balance and reduce the effect and the stable productivity level be attained in short time.

2. **Advancement in Quay Crane**

   The advancement in quay cranes such as attaching multiple spreaders can be unique way to tackle the waiting time in the quay area and match the quay crane productivity with the yard feeding rate. However, in this scenario the researcher suggests that CTOs can eliminate the use of ITVs for yard feeding. The cyclic boom (refer with multiple spreaders on the quay cranes can be used for yard feeding, i.e., the loading/unloading operation from/to the vessel can be followed by yard operations. The boom of the quay crane must be extended upto the yards. This means that quay cranes will be directly connected to the container blocks.

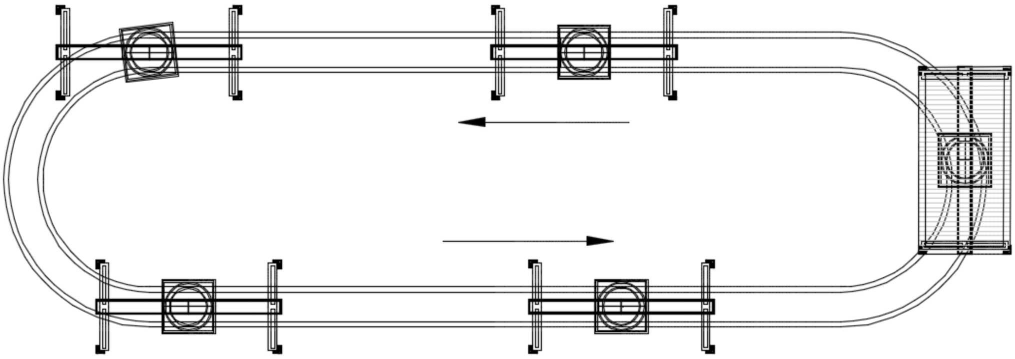


Figure 19 - Cyclic boom for quay crane

In this scenario, the need for balancing the yard feeding rate vs quay crane productivity can be overlooked, as the ITV for yard feeding is eliminated totally. The terminals who are labour dependent can train the ITV fleet force for operating the multiple spreader system to operate in sequential manner. The planners, TOS developers and researchers will need to come with a mixed integer programming for managing the vessel loading/unloading and the multiple spreader operations. For container terminals it will reduce the cost of handling and reduction of steps in the terminal supply chain.

Figure 20 - Future container terminal like an automated warehouse

The final designing and manufacturing of this quay crane will be a challenge for OEM operators and post-deployment the operational time is believed to be difficult. However, the CTOs it is combination of several technologies like BOXBAY and cyclic quay crane boom that has multiple spreaders. In short terms a replication of AS/RS warehouse should be implemented and deployed in a container terminal.

5.2 Limitations of Research

The research focuses on some variables and factors and does not cover the purely technical side of it. The limitation to research existed due to the lack of actual technical data and limited number of respondents. The researcher has tried every to understand the terminal layouts and equipment used by the company websites, Google maps and Google earth engines (Basic and Pro). Therefore, a general layout of the terminal was built and focused on. The research could be more insightful if the data for propositions was available abundantly. This suggests that prospects for giving a technical solution would be on the main agenda list.

5.3 Future Research

Future research can be focused on the programming side and cost-saving side of the container terminals. The agent technologies are gaining popularity in the common public and later can be installed in container terminals for doing the major work of planning and scheduling the movements of equipment. Another element of the agent technology is that it can be utilized to keep a track record of maintenance or wear n tear of the terminal equipment or calculating the energy consumption units by each ITV. Additionally, the container terminal efficiency and productivity can be improved by other management sides by using the smart storage policies.

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