Development of conceptual model for Main Line Container Vessel Berth allocation in a Transhipment Container Terminal

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I. Declaration of Originality

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Dr.Indika Sigera

Abstract

Berth allocation is essential for efficient terminal utilization in container ports and it can identify as a most critical activity which should manage in strategic ways to achieve long term benefits. Previous studies have empathized that, Port/ Terminal congestion i.e unexpected waiting times before berthing, as a main factor which affects to the schedule unreliability in container Shipping. Terminal operators' objective is to minimize the sum of port staying times of container vessels while maximizing berth occupancy of terminal and that minimizes dissatisfaction of the ships in terms of the berthing order. Main container Shipping lines strive to maintain their sailing schedules to manage expected level of schedule reliability. Focusing on that, this research is aimed to develop a common model which beneficial to both Container Terminal Operators & Shipping Lines when arranging berths in container terminals. The study was focused on main line container vessels' berth allocation practices in Transshipment container terminals. Analysis of the study was carried out from both Terminal operators' and Shipping Lines' aspects. Eight criteria have identified from terminal operators' aspect which are consider when allocating and prioritizing berths for incoming container vessels. From the Container shipping lines' aspect eight criteria have identified which are consider by them when requesting berths for their vessels. Finalized criteria from both aspects were structured in to two questionnaires and one sent to the managerial level of selected ten major transshipment terminals and other one sent to the ten leading container shipping lines in world. Collected expert judgments regarding the subject criteria was analyzed using Analytical Hierarchy Process (AHP) technique and as a final outcome those were ranked based on the weight assigned. Products of the two aspects were combined to develop a common model which considered to be as a win-win approach. Common criteria from both aspects have extracted to develop a product of two matrixes. In common model criteria named "Berthing Pro-Forma" ranked as a most critical and important one having weight of 0.2701. Other seven criteria were ranked based on the calculated weights as Punctuality of service (0.2255), Investment in terminal (0.1791), Liner connectivity (0.1268), Commercial aspects (0.0862), Relationship and market power (0.0537), Service agreements and policies (0.0317) and Special requirements (0.0222). Since mentioned eight criteria make a positive impact on the berthing arrangement equation has developed by adding those together. Within this study applicability of the modal to the real-world berth allocation problem have discussed as a final step of the analysis. As currently practiced in container terminals, berth allocation has done based on the practical experience and intuition of relevant professionals and it was an activity they daily performed. Since they are focusing on this as a day to day activity, in long term negative impacts can occur due to customer dissatisfaction. This happens because terminal operators and shipping lines are working separately to achieve their individual objectives by neglecting the importance of mutual agreements. That gap will fill by this study and developed model can use in berth allocation which may generate long term mutual benefits to both parties. Future studies can be focusing on to apply the same concept in feeder line operation and any type of port terminal.

Key words: Berth Allocation, Port staying time, Transhipment terminal, Analytical Hierarchy Process, Schedule reliability

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List of Acronyms

AHP	Analytical Hierarchy Process
TEU	Twenty-Foot Equivalent Unit
ITT	Inter Terminal Trucking
FCFS	First Come First Serve
THC	Terminal Handling Charges
ETA	Estimated Time of Readiness
BAP	Berth Allocation Problem
QC	Quay Crane
MUT	Multi User Container Terminal
KPI	Key Performance Indicator
TSA	Terminal Service Agreement

1 Contents

As per the APH model findings; Berth Allocation is influenced by several critical parameters which varies from high importance to low importance and the regression analysis method has been carried out to define the significance of each independent variable to dependent variable of Berth Allocation. Thus; based on the interpreted data which are gathered from the

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1 Introduction

1.1 Background of the Research

1.1.1 Introduction

There are no any doubts for maritime transport is the backbone of global trade and global economy. Everybody in the world benefits from shipping and it helps to ensure that the benefits of trade and commerce are more evenly spread. There is no country sustain as self-sufficient and everyone relies on maritime trade to sell what it has and buy what it needs. As the world's population continuous to grow, especially in developing countries, low cost and efficient maritime transportation has an essential role to play in growth and sustainable development. Roughly 90% of global cargo is moved by vessels, and most of general cargos are transported in containers. Accordingly, a container terminal becomes one of the important nodes in the global supply chain network and it is important for container terminals to operate efficiently.

Based on the above facts both shipping lines and sea port operators should work collaboratively to secure the flow of global supply chains. In this kind of environment both container Shipping lines and container terminal operators should work together to achieve anticipated time sensitive targets.

Table 1.1.1-1: Source of Schedule Unreliability, on the East Asia – Europe route – fourth quarter 2004 (Notteboom, 2006)

Source of schedule unreliability	Percentage	Port Related Source
Port/Terminal Congestion – unexpected waiting times before berthing or before starting/loading or discharging	65.5%	Yes
Port/Terminal Productivity Below Expectations (loading/discharging)	20.6%	Yes
Unexpected Waiting Times – due to weather or on route mechanical problems.	5.3%	No
Unexpected Waiting Times - in Port Channel Access (pilotage, towage)	4.7%	Yes
Unexpected Waiting Times - in Port Channel Access (tidal windows)	2.8%	Yes
Suez Convoy Missed	0.9%	No
Unexpected Waiting Times – at bunkering site /port	0.2%	Yes

It can observe that in many occasions vessel schedules change and make shipping more challenging to the Exporters and Importers. It can be difficult and very costly to manage all these vessel delays for any party in supply chain. Considering above fact most of the leading Shipping Lines are striving to maintain their sailing schedules as planned and there are several identified factors those are directly affecting to schedule reliability.

As clearly analyzed in above table no 1, there are container port related factors and other specific factors can categorize under this. Unexpected delays can occur due to serious weather conditions on route and due to mechanical failures. In addition to that carriers may missed the Suez or panama windows and they must wait even days to get next chance. Those kinds of factors can consider as non-port related factors and the impact of these factors to schedule reliability at minimum levels.

On the other hand, most important factors are port related factors those are directly affecting in maintaining schedule reliability. As per the analyzed data illustrate in Table 01 “Port/terminal congestion i.e unexpected waiting times before berthing” identified as a most critical factor which decently affects in this subject considered. As a next affecting factor, they have indicated that “Port /Terminal productivity level” as well.

Considering above facts, it’s very much important to focusing on the most critical factor since as a percentage 65.5% it affects to the subject matter. In most of the container sea ports especially in transshipment hubs average waiting times considerably higher due to heavy congestion. As per the analysis done by Port Technology in 2015, Singapore received the most container ships in September and recorded a total of 1,382 ships for the month, with average waiting times (AWTs) edging up to seven hours. On the other hand, Jebel Ali saw the least number of ships call at its port in September 2015, recording a total of 451 ship calls, with an average waiting time of 9.8 hours (Port Technology, 2015). Maintaining that figures in 2015, according to the newest analysis done in 2016, Port of Busan records the lowest waiting time as port’s average waiting time increased by up to five hours) Port Technology ,2016).

On the one side shipping lines strive to maintain their sailing schedules and from other side terminal operators trying to allocate their berths available to their incoming vessels. That means terminal operators need to allocate their available berths to different vessels deploy in different services owned by different shipping lines according to some developed model. In fact, they have to allocate berths to container vessels based on some particular criteria.

In the situation where if particular vessels didn't get the berths in container terminals as requested, there are some tactics which could be employed by carriers to revert the schedule as to reshuffle the order of ports, skip a port completely, employ cut and run tactics (reduce the declared containers volume to be handle at particular terminal), deploy other vessels to take over in combination with a delivery to a hub, look to speed up future port turnaround times, increase vessel speed between ports – especially on inter-continental legs. The reason to apply above indicated tactics to maintain schedules is shipping lines are legally bound to deliver shipments to their customers on time without delay.

Considering above indicated facts, berth allocation in a particular container terminal can consider as a one of the critical activity should be handle in strategic way. The reason is that as most of the container terminals in world maintain window berthing system and they manage multiple Shipping Lines both having main and feeder services. Usually main lines maintain weekly services and each and every week they bring one vessel for one particular service which request the berth in calling terminal. In such kind of situations each and every main line vessel bargaining for having particular berths in terminal as soon as possible with maintaining minimum waiting time by putting container terminal operators in pressure.

As clearly defined berthing arrangement in container terminal operation can consider as one of the most important activity. Within the concept of the dedicated berth planning the complexity is in minimum level as every shipping line (Dedicated Customers of terminal) have assigned berth to follow. The reason is few shipping lines/alliances are operating in one terminal & in most instances those shipping lines owns the terminal. But with the Pro-Forma berthing arrangement complexity increases as when deciding the particular berth for a container vessel there are multiple criterion should consider. Due to complexity decision making in berth allocations most of the times in problematic situation. That's most important to use developed framework when allocating of berths for container vessels.

In berth planning there is a tradeoff lying as a shadow which may critically affects to the Terminal and Shipping lines as customers. From the view of Container terminal which operates on window berthing arrangement basis, they need to manage their larger number of customer base in the way that by giving better service level to retain them **and their main objective is maximize the berth utilization level.**

On the other hand, shipping lines expectation is **to have a better service level from the terminal** based on their specific requirements.

Ultimately when allocating the particular berth for vessel there should be some kind of win-win situation for both container terminal operators and Shipping lines. Simply there should be framework for mutual understanding which can follow by both parties when allocating and requesting for berths in a container terminal.

1.1.2. Aim of the Research

This research aims to develop a common model which beneficial to both Container Terminal Operators & Shipping Lines when allocating and requesting berths in container terminals.

1.1.3. Objectives of the research

- The main objective of this research is developing common model which can use when allocating berth to container vessel which beneficial for both shipping line and container terminal.

To support main objective there are three sub objectives as,

1. Identify and categorize the unique factors consider by container terminal operators when allocating berths for main line container vessels and identify and categorize the unique factors consider by Shipping Lines when requesting berths in container terminal
2. Weight and rank the criterion that Container terminal operators consider when allocating berths in their terminal and criterion that shipping lines consider when requesting a berth in container terminal
3. Identify and rank the common factors consider by both Terminal operators and Shipping lines in berthing arrangements
4. Develop a regression model & application to the real-world berthing arrangement

1.1.4. Limitations of the Research

Today in maritime industry transshipment can identify as a developed activity. With the growth of long distance containerized trade, intermediate hubs grew in importance in helping connect different systems of maritime circulation. The emergence of major intermediate hubs favored a concentration of large vessels along long distance high capacity routes while smaller ports could be serviced with lower capacity ships. Globally based on the geographical distribution, seven major transshipment markets accounting for the bulk of the transshipment activity. Considering this emerging trend and competition among the current major transshipment hubs within this study focusing on the berth arrangements practiced in transshipment ports only. By using world transshipment sea port ranking for data collection and analyzing purposes only consider for the survey around 10 container terminals those possible in getting information and feedback. Not only that the research study also limited to the “Multi user container Terminals” which may define as terminals with a long quay where a number of incoming vessels are simultaneously and dynamically allocated to the quay and are not always assigned to specific same quay locations whenever vessels call. The multi user terminal is widespread system in use, especially in busy container ports with heavy container traffic.

Berth allocation for main line vessels can identify as a most challenging task in a particular transshipment container terminal. Especially feeder vessels berth allocation is purely depending on the berthing arrangements of main lines. The reason is feeder lines are 100% depends on the main line container volume and their berthing arrangements also consider aligning with main line vessels. On the other hand, main lines strictly follow their sailing schedules. Considering that fact they always strive to arrange berths in transshipment hubs by reducing waiting times and considering any other special requirements. Based on that within this study focus on berth allocation of main lines’ and as per statistical analysis in maritime industry more that 75% of volume (in TEUs) and majority of vessel fleet handle by top 10 carriers (Alphaliner, 2017). According to that figure said 10 main lines take in to consideration in analysis since they handle and dominate the container trade.

There are some unique factors consider by both terminal operators when allocating berths for vessels and on the other hand there are another set of factors consider by container lines when requesting berths in a container terminal. Within this research focusing on the factors those are within control limits of terminal operators and Shipping Lines and factors commonly considered. There are some special considerations and criteria like government intervention, policies etc consider when allocating berths for container vessel those under special categories. Those kinds of situations are excluded from analysis since beyond control and not commonly in practice.

As current berth allocation is done by using tacit knowledge which have developed by experience, when developing a model and proving it as beneficial to both Shipping lines and terminal operators used qualitative data in some areas. This is mainly due to unavailability of quantitative data and impossibility in proving the win-win situation using mathematical models.

1.1.5. Significance of the research

As clearly mentioned, today maritime transportation plays major role in intercontinental cargo movements. Since supply chain partners are spreading across the world, each and every component of supply chain should be connected on time without delay. Based on that Shipping lines and container terminal operators have to play major role in this connection and they have to work together to achieve acceptable targets. Especially managing berth allocation to arriving vessels is critical in multi-user terminals, since poor choices can cause unnecessary delays in ship processing and resultant carrier dissatisfaction by making big losses to both parties.

Focusing on the berth utilization rate of the container terminals it’s higher in multi user terminals where performs pro-forma berthing system and its lower in dedicated berth systems. Due to that fact it can clearly identify the impact of proper berth planning for the entire operation of terminal.

Since multi user terminals usually manage the larger customer base with different types of services there should be framework which can be use strategically when allocating berths for their vessels. As currently practices berth allocation for the container vessels done by considering multiple criteria and from the other side shipping lines also consider several criteria when requesting for berths. This decision they have to take daily and have to manage this in a way that by satisfying Shipping lines and gaining long term advantages to the terminal as well. At the initial stage of terminal operations and even currently in some of the terminals use first come first serve (FCFC) method when allocating berths. That means whenever the vessel arrived at first and if everything is in order including documentation, payments, approvals etc. that vessel will be berth first. Following that concept multi user terminal operators develop a concept called pro-forma berthing (window berthing) concept where each and every shipping lines can obtain a particular time slot for berth their vessels which are deploy in particular routes. As per the current situation in maritime industry due to severe competition, container terminal operators difficult to strict to the first

As per the current situation even berth planners consider multiple set of criteria when allocating a berth for container vessels. Majority of researches conducted based on the berth allocation problem which directly dealing with the optimization of vessel arrival time with the objective to maximize the ocean carriers' satisfaction (minimize delays) and/or minimize the terminal operator's costs. Other than that, there are some most notable objectives addressed in those literatures are Minimization of vessel total service times (waiting and handling times), Minimization of early and delayed departures, Optimization of vessel arrival times, Optimization of emissions and fuel consumption. Here as input data use vessel length, expected vessel arrival times, estimated handling times and berth layout. As output of the analysis delivered berth schedule including berthing position, berthing time & completion time. As analyzed those researches are only focusing on one particular attributes in berth planning specially towards the technical aspects. But the importance of this research is considered technical and commercial aspects in berth allocation systems which were not studied in previous studies.

Especially allocation of berths in a container terminal is a strategic decision and shouldn't think as a tactical or medium-term decision. The reason is, as clearly defined shipping lines strive to follow their service schedules as much as possible by maintaining higher level of schedule reliability to satisfy customers. On the other hand, multi user container terminal operators manage customer base of in generally more than ten main Shipping lines. Then they have managed them to survive in competitive environment and if as an example if they were unable to assign berth for one particular vessel may cause to loss that entire shipping service. Considering this scenario, it's very much important to analyze the criteria consider when allocation of berths from both aspects i.e Terminal operators and Shipping lines and from both commercial and technical aspects as analyzed with in this study.

Due to that fact this study will useful for both Shipping lines and multi user terminal operators in long run to gain many advantages as it covers all the attributes which covers commercial and technical aspects.

1.1.6 Chapter breakdown

This thesis consists of five main chapters in order to achieve the ultimate objective of the research. Chapter 1 gives an overview about the background of the study area with the brief introduction to apparel industry in Sri Lanka. The need for the research, research problem and objectives are identified and the significance of the research is justified. And scope and the limitations of the research are focused. Through the chapter 1, reader will understand the basic idea of the research and the importance of the research.

Chapter 2 was structured to establish the theoretical framework for the research and identify the berth planning practices and relevant criteria consider. And this chapter is the basis for identifying the analyzing method and the methodology. This consist the previous literature reviews and their findings with relevance to this research.

Chapter 3 explains the methodology used to reach the research findings. This will explain the research design, data gathering methods used population, sample design and the analysis method. A comprehensive idea about designing of the questionnaires can be gained after reading this chapter and the analysis methods has been explained in detail.

Chapter 4 was structured to present research findings. Here finalized criteria in berth planning process have analyze from both terminal operators and Shipping lines perspectives. Analytical Hierarchy Process technique use for the analysis.

Chapter 5 was structured for the conclusion and future research directions. It consists summary of research findings, recommendations, research limitations and future research directions.

2 Literature review

2.1 Global maritime industry and its importance to Supply chain

As in today world Supply chains are widening across the continents need for maritime transportation became a most significant factor. Majority of the industries use maritime transportation for fulfill their transportation requirements due to various reasons. As global supply chains have become more complex, seaports need not only be global hubs in logistics networks, but they must also act as central nodes in organizational and information networks. When all three of these networks are connected, they can create economic value, improve environmental performance, and enhance security in global trade (Zuidwijk R, 2015).

Under supply chain concept, Supply chain integration can be identified as an emerging fashion where manufacturers strategically collaborate with their supply chain partners to manage intra- and inter-organizational processes, in order to achieve effective as well as efficient flows of products and services, and to provide maximum value to the customer. As shipping is a vital component in global supply chains, it is important for maritime logistics service providers to be embedded well in this system (Ming Ling S., 2014).

Different types of products produce, and natural resources available in different areas of the world and with the globalization and extended supply chains people tend to exchange those among them. The Need for maritime transportation emerge as a solution for this trading of commodities among nations. As shown in below map it can clearly identify that how natural resources located and how commodities are manufacture in different areas of the world.

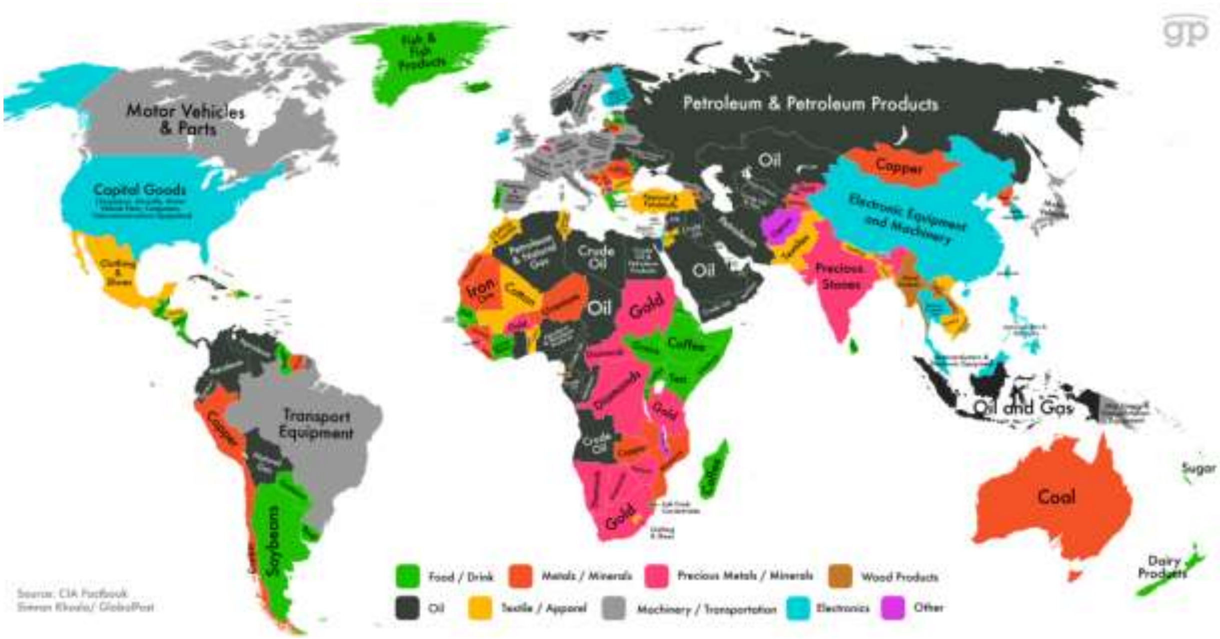

Figure 2.1-1: Export commodities and raw materials in world based on the geographical distribution, CIA Fact book, 2014

Different types of vessels and sea ports have developed based on this and currently containers use to transport majority of commodities.

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The development of intermodal transportation, including the deregulation of the transport industry, is conductive to a functional integration among supply chains. The benefits of this integration can be assessed in a number of ways, particularly in terms of overall transport cost and time reductions as well as a better reliability of the supply chain. The below figure shows the different stages of functional integration along a supply chain involving maritime and inland distribution. Considering the integration of maritime and inland distribution most of the shipping lines strive to provide door to door services to their customers on time. To facilitate this, they have their own inland transportation solutions as well. For an example currently, world third largest container carrier CMA CGM has its own multimodal network covering each and every region in world. Such kind of integrated networks also pressure the container terminal operators by requesting fast service level to their vessels. In this kind of situation terminal operators have to improve their productivity levels and also berthing arrangements in a way which facilitate to their massive multimodal networks.

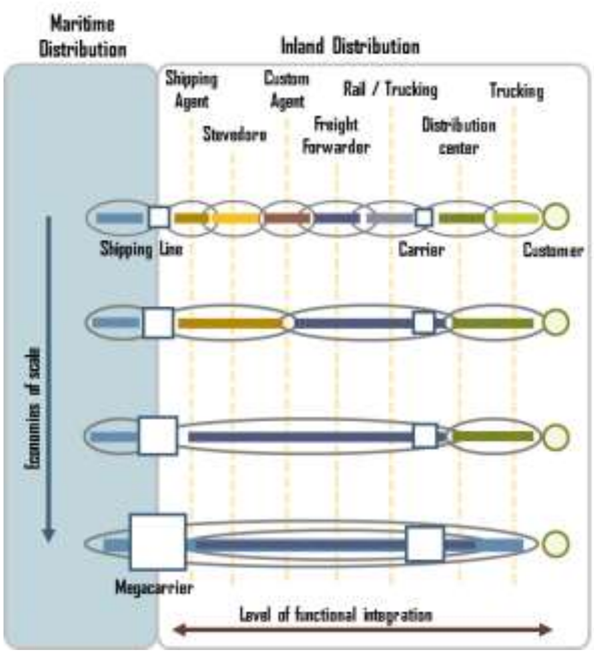


Figure 2.1-2: Functional integration of Supply Chain

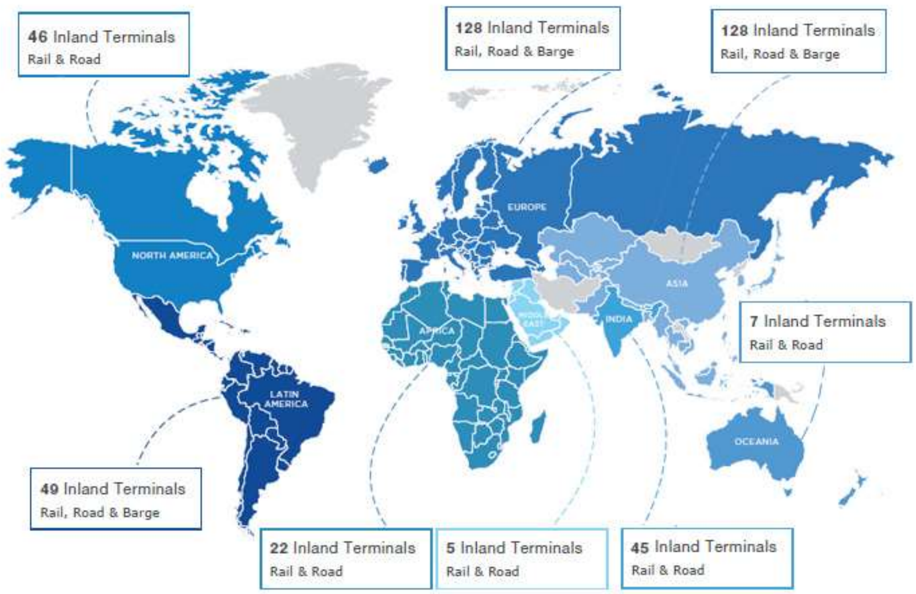


Figure 2.1-3: CMA CGM Multimodal Solution

With the development of the concept of supply chain integration, with respect to that world merchandise trade is continuously increasing and following that world seaborne trade also has growing trend. As shown in below graph it can clearly identify the growing trend of world seaborne trade.

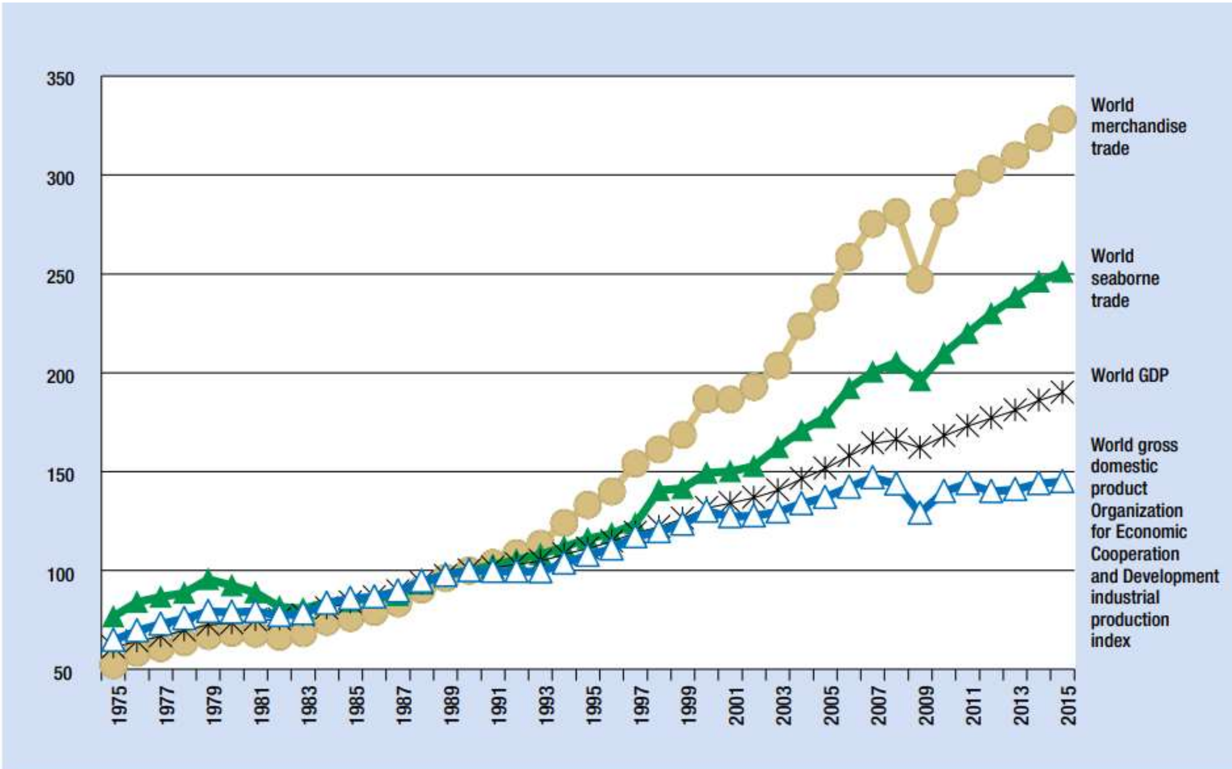


Figure 2.1-4: Organization for Economic Cooperation and Development industrial production index and indices for world gross domestic product, seaborne trade and merchandise trade, 1975–2015

2.2 Main routes and trading areas in container Shipping

It’s important to consider regarding the trading pattern of the container transportation since container ports / terminals positioned along the trading routes and major geographical areas where cargo flows originate. As Cleary shows in below figure East Asia – Europe route can identify as most congested container shipping route

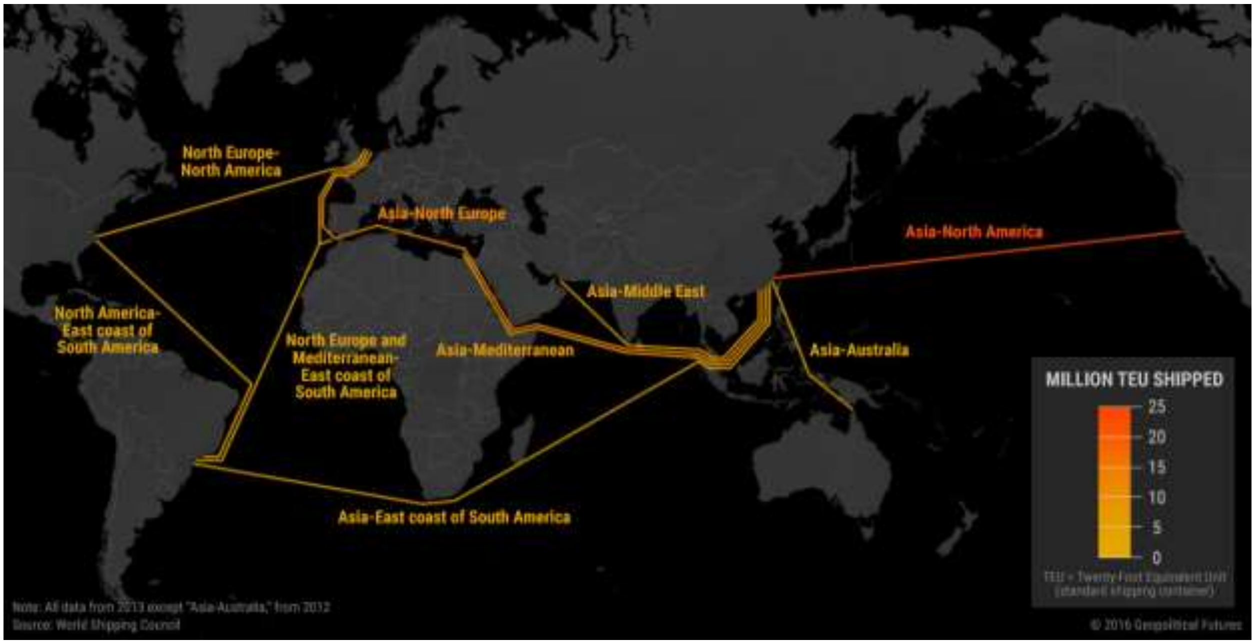


Figure 2.2-1: Top container ship trade routes

The above graphic shows the world's top trade routes for container shipping, measured by millions of standard containers shipped. According to the United Nations Conference on Trade and Development (2017), around 80 percent of global trade by volume and over 70 percent of global trade by value is carried out over maritime trading routes.

According to the analysis the route between Eastern Asia- North America has highest cargo traffic and trade lane between Asia – Europe state in second place. Other than those two trade lanes respectively North America- Eastern Asia/Europe –Asia/Europe – North America and North America – Europe trade lanes handle majority of containerized cargo flows (UNCTAD,2017) as clearly shown in below figure no 2.2.2.

As mentioned those trade routes plays most important role in container trade and majority of sea ports located along those routes. Container ports and terminals have to play major role in handling this volume along the trade lanes mentioned by facilitating to handling of container flows. In the case of handling these trading container flows the concept of hub port emerged and currently these strategically located ports plays significantly important role in maritime transportation.

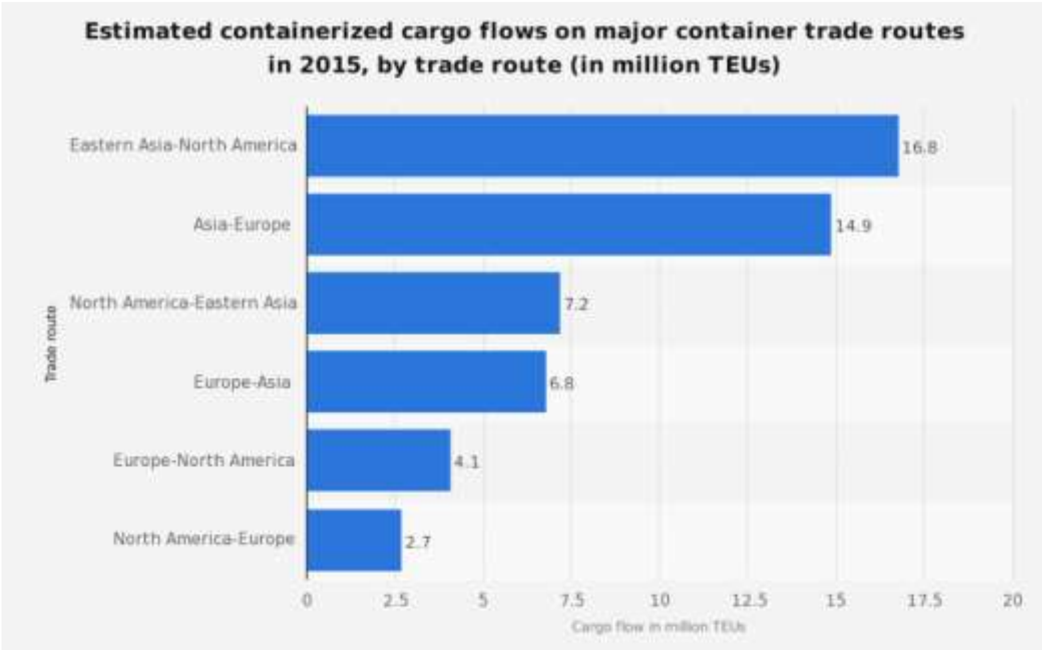


Figure 2.2-2: Estimated containerized cargo flows on major container trade routes in 2015

2.3 Hub port development and future trends

With the development of containerized trade in long distance, intermediate hubs grew in importance in helping connect different systems of maritime circulation. These intermediate hubs located along the main circum-equatorial maritime route that goes through panama, the Strait of Malacca, Suez and Gibraltar. Especially from these maritime hubs it connects the maritime trade lanes between North-South and east-west.

As clearly shows in below figure no 2.3.1, there are seven major transshipment markets identified. Transshipment hubs are competing for the traffic related to region/market. In this scenario geography plays an important role in setting of a transshipment market, which is often at the cross roads of north/south Shipping routes and where the market is a bottle neck (Jean R., 2017).

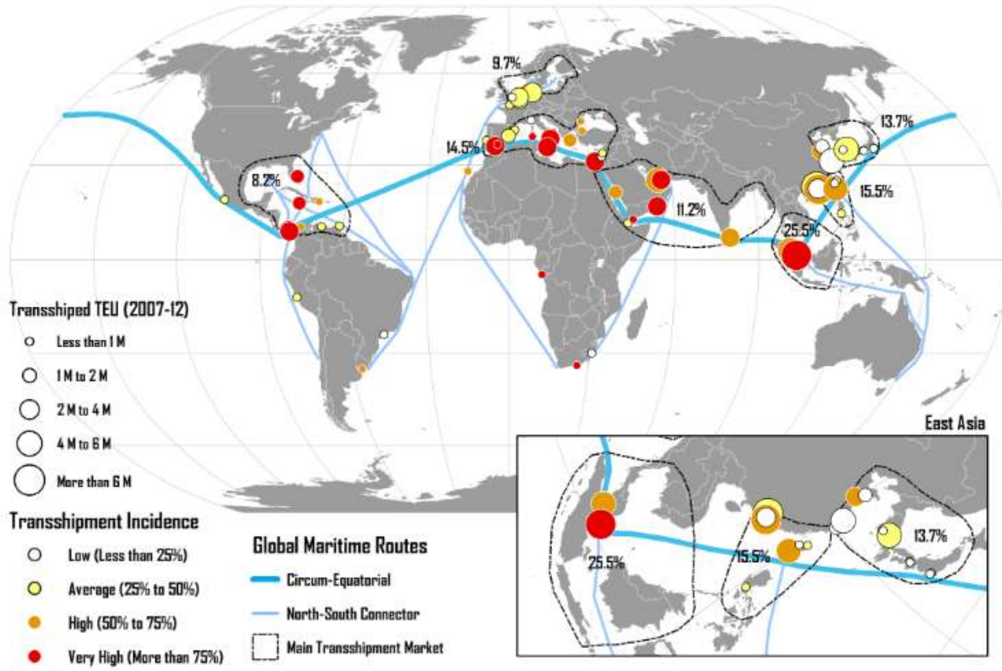


Figure 2.3-1: World Transshipment hub, Geography of Transport systems

Considering above facts as per the current situation Singapore can identify as a world's most important intermediate hub where 85% of the traffic is Transshipment. There can be possibility in shifting transhipment dynamics due to the changing commercial environment. For an example, transhipment incidence levels in the Japanese ports of Tokyo and Yokohama used to be in the 20% range, but have declined to less than 10% as Japan was losing its role as a manufacturing center with many transhipment activities shifting to Korea (Specially to port of Busan) or China. The Mediterranean has only two points of entry (Suez and Gibraltar), both of which have significant transhipment activity, as well as ports that are at the center of the basin (ex. Marsalokk and Gioa Tauro). When focussing on the Caribbean region it has one outlet for the pacific due to Panama Canal which has significant transhipment activities both on the Atlantic and Pacific coasts. The North Sea and the Baltic are another transhipment market, but having lover volumes (Jean R., 2017).

As clearly identified there can identified the seven major transshipment regions in maritime world. There are also major transshipment hub port competing each other to attract the container vessels to increase their handling volume. Also, they develop their infrastructures and improve quality levels to provide efficient service level to Shipping lines with the objective of being a leading transshipment hub of region. In this kind of critical situation, it's very much importance and need to be focusing on the areas where shipping lines concerns when selecting container terminals over another. Considering this it can clearly identify how much berthing arrangement is important in this Transshipment based sea ports. The main reason is Majority of Shipping lines develop their route networks by adding these transshipment hubs in to those because by using those hubs they can reach to majority of captive markets using feeder networks and land side networks.

The most significant benefit is the income generated from operations of a transshipment hub because of the double handling of containers. Consequently, container throughput in hub ports can be greatly boosted, particularly when expressed in TEUs. More importantly, transshipment hubs provide local importers and exporters direct access to line haul service, reducing transportation time and most probably freight cost to and from overseas markets as well. Reduced transport time directly affects the competitiveness of exporters and the cost of imports, in turn creating jobs and income throughout the economy. Many developing countries have created free trade zones in combination with the hub port as engines for economic growth (World Bank Transportation Division, 2007).

2.4 Forms of Transshipment

Even if all transshipments are the same from an operational viewpoint, moving containers from one ship to another using a port as a temporary buffer, they take place in three main forms servicing a different purpose. The first form is named as hub-and-spoke transshipment, which connects short distance feeder lines (and ports) with long distance deep-sea lines, linking regional and global shipping networks. The transshipment hub is usually a central location commanding access to a region. Ship capacity differs significantly between deep sea and feeder services. While the former usually involve the largest ships technically possible, feeder vessels are usually much smaller.

The second one is named as intersection transshipment. At there transshipment hub acts as a point of interchange between several long-distance shipping routes. It usually involves the movement of cargo between large ships since deep sea routes are prone to economies of scale. The third forms involve relay transshipment where the transshipment hub connects shipping routes along the same region, but servicing different port calls. Ship capacity can differ since regional routes can be serviced by smaller ships. Hub-and-spoke transshipment account for the great majority of transshipments (around 85%) while intersection and relay transshipment account for the remaining 15% of all transshipments. Irrespective to the type transshipment reliability can identify as a major element in three cases and berth allocation plays critical role in this.

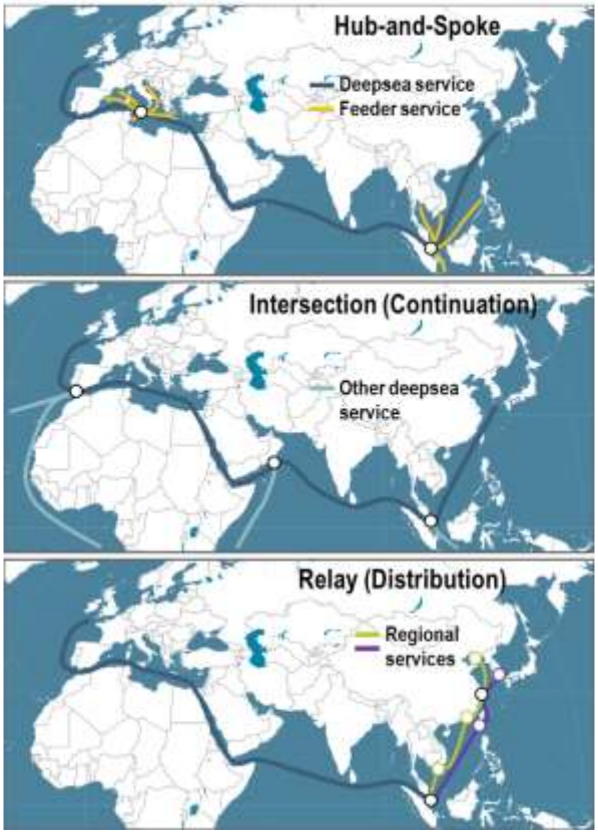


Figure 2.4-1: Three forms of transshipment in maritime transport

The level of transshipment activity of a port can be measured by their transshipment incidence, which is the share of the total port throughput that is “ship to ship” compared with the total throughput that includes hinterland traffic as well. The higher it is, the more a port can be considered as a transshipment hub. For ports with low transshipment incidence (less than 25%), transshipment is an incidental activity, while ports having a transshipment incidence above 75% can be considered as “pure” transshipment hubs (particularly if their transshipment incidence is above 90%). On the map below the world’s most important pure transshipment hubs are shown in red in figure 2.3.1.

2.5 The future of Transshipment

In the past years, in world transshipment incidence has stabilized in the 28-30% range, implying that transshipment is now a mature activity. Future growth is thus likely to be in proportion to the growth of global container traffic, but which factors could further increase the scale of transshipment is problematic. One important issue relates to the ongoing introduction of larger containerships calling less ports, which is inciting a greater reliance on transshipment. Further, the expansion of the Panama Canal will favor the setting of circum-equatorial deep-sea services with north/ south connections, increasing the dependence on transshipment. This may be counterbalanced by port growth in developing economies such as in Latin America and Africa, which could incite more direct services with Asian, European and North American ports. Still, it remains likely that with further economies of scale and rationalization in maritime shipping (focus on selected deep-sea routes) that the global transshipment incidence could reach 35%.

Because of geographical considerations, transshipment markets are unlikely to change, but which ports are the dominant transshipment hubs of these market could. The transshipment region could be stable in its level of transshipment activity while its individual transshipment hubs could experience fluctuations in their market share. The usage of transshipment hubs remains a decision made by maritime shipping companies that do so to organize their shipping networks. Such decisions can change if a company revises the allocation of its assets and its commercial strategy (Rodrigo J, 2015).

2.6 Container Terminals and their importance in shipping

Mainly container terminal has four main activities as ship to shore operation, waterside horizontal transport, storage activities and hinterland connectivity. These four main types of activities clearly show in below figure no 2.4.1.

Most importantly when the ships arrive, terminal need to allocate suitable berths to those prior commence the loading and unloading operations. In addition to above mentioned activities, berth allocation in a container terminal considered and identified as a most critical activity which act as an initial point where contact customers i.e .shipping lines

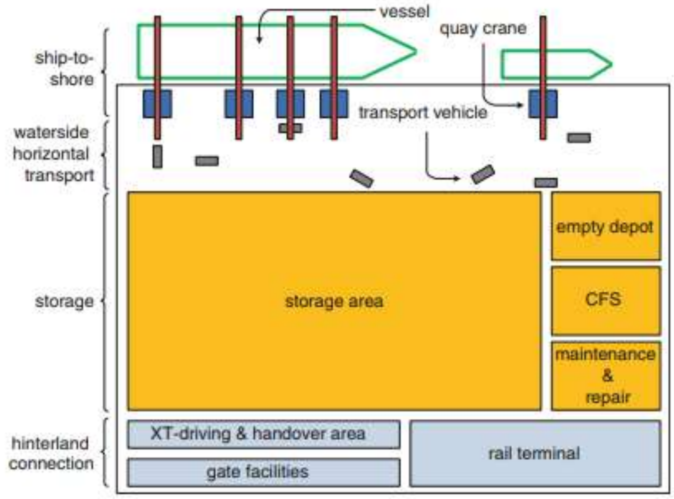


Figure 2.6-1: Container terminal operations layout

Berth allocation as most critical and important activity in a container terminal each and every terminal follow their own set of criteria when allocating berths for incoming container vessels. For an example as shown in below figure no 2.6.1 container terminals have their own sequencing policies such as "First in First out", "Highest Earning first" or "Shortest job First".

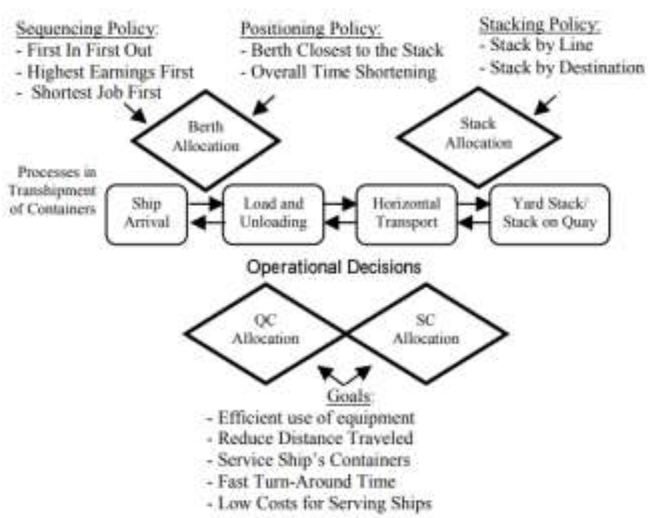


Figure 2.6-2: Operational procedure of container terminal, Evaluating Container Terminal Transshipment Operational Policies: An Agent-Based Simulation Approach, Lawrence H

2.7 Selection criteria of container terminals by shipping lines

Shipping lines consider unique set of criteria when selecting container terminals for berth their vessels along the routes they have developed. When consider about the designed route for particular service they tend to select port rotation in a strategic way while considering multiple set of criteria.

Those criteria includes geographical location, water draft, feeder connection, inland intermodal/hinterland connection , scope of hinterland (large/small), port reputation, port dues, Terminal handling charges, handling speed/efficiency, service reliability, cargo volume (transshipment/domestic), cargo profitability, **Berth availability**, information technology ability, convenient of customs process, relationship between management and workers, acceptance of special requirements, easiness of communication with staff, calling of competitors and slot exchange with cooperating lines (Wang L., 2010).

Geographical location: when focusing on a port's physical conditions, geographical location is always the first factor that comes into one's mind. A port's location usually plays an irreplaceable role in sea transportation. Especially when consider about the transshipment operations geographical location of the transshipment hubs plays a major role.

Water draft: As containerships tend to be larger and larger because of economies of scale, today's largest containership could have a draft of 16 m. With that a port with insufficient draft may become a feeder port in a hub-spoke system.

Feeder and Inland intermodal: Ports not only compete for cargo but also compete for hinterland. A good connection to hinterland through multimodal transportation means both quicker access to customers in hinterlands and larger hinterland than competitors. Furthermore, high qualified inland intermodal infrastructure and efficient connection to hinterland strengthens a port's role as a logistics hub in supply chain.

Port reputation: It's considered as a port's overall quality or character as seen or judged by its stakeholders in generally. It is difficult to quantify and it may be not the same in different stakeholders. Especially transshipment hubs have good reputation among the other sea ports.

Hinterland: Usually larger hinterland brings more customers and business to the ports. In practical scenario, hinterlands for different ports may overlap to some extent, for example, port of Rotterdam shares part of its hinterland with port of Amsterdam and port of Antwerp. The economic and political condition of hinterland also affects port choice. Hinterlands with high economic performance usually have more logistics needs and thus the port will benefit more from it.

Terminal handling charge (THC): These are essentially charges collected by shipping lines to recover from the shippers the cost of paying the container terminals or mid-stream operators for the loading or unloading of the containers, and other related costs borne by the shipping lines at the port of shipment or destination. If the charges are favorable to shipping line with rebate scheme they will tend to select those ports in their network.

Handling speed/efficiency: Handling speed/efficiency can be defined as the total number of container moves of gantry cranes in a container terminal within a single unit time. Basically, Gross Crane Productivity considered as most important KPI under this.

Service reliability: Port service reliability contains at least three key elements, accessibility, continuity and performance. Accessibility means that port services are available when shipping lines need them; continuity means shipping lines have uninterrupted service over desired duration and performance means that shipping lines' expectations can be met.

Cargo volume: Cargo volume is call size or loading and unloading cargo for shipping lines in a particular port of call.

Berth availability: This is a state that when vessel needs to be operated at berth, the berth is available for the vessel to do that. The time window of a berth represents the berth availability period. One side Shipping lines tend to be in favor of high berth availability while ports tend to be in favor of low berth availability. Because high berth availability ensures service quality and availability whenever shipping lines come to the port and low berth availability means that the utilization of port infrastructure is high and thus ports could earn more from it (Saanen, 2011).

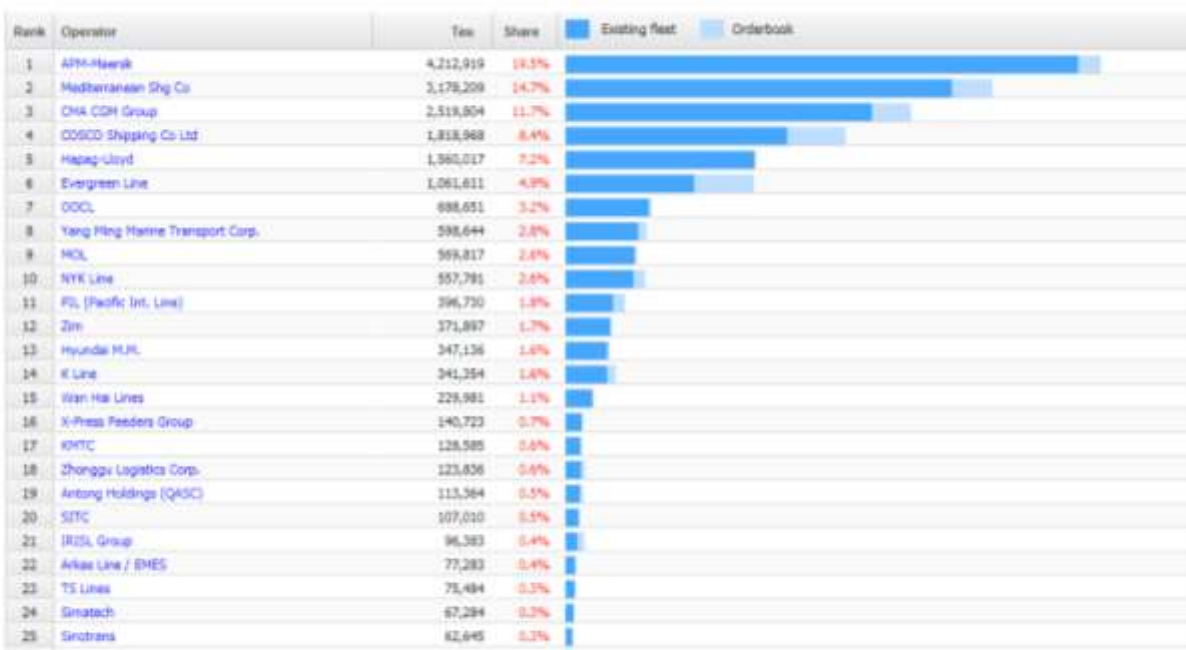
Information technology ability: Better Information Technology (IT) system condition in both port and shipping line can promote coordination between shipping lines and port and even any other logistics parties.

Relationship between management and workers: Relationship between management and workers reflex the level of a port's management and organization. Mennis et al. (2008) remarked that the strikes are one the main reasons for delay in terminals. Shipping lines of course prefer ports with good relationship between their management and workers in order to make operations smoothly.

From analyzing above indicated criteria it can clearly identify berth availability is a main criterion which shipping lines are focusing on when selecting ports/ terminals in their service networks.

2.8 Structural developments in shipping lines and trading patterns

As per the current situation more that 85% of world container shipping trade is handle by 18 carriers (Alpha liner, 2017). Not only that due to severe competition among Shipping Lines except few, most of them operates as alliances.



Rank	Operator	Teu	Share
1	APM-Maersk	4,212,919	19.5%
2	Mediterranean Shg Co	3,178,209	14.7%
3	CMA CGM Group	2,519,804	11.7%
4	COSCO Shipping Co Ltd	1,818,968	8.4%
5	Hapag-Lloyd	1,560,017	7.2%
6	Evergreen Line	1,061,611	4.9%
7	OOCL	688,651	3.2%
8	Yang Ming Marine Transport Corp.	598,644	2.8%
9	MOL	569,817	2.6%
10	NYK Line	557,781	2.6%
11	PIL (Pacific Int. Line)	396,730	1.8%
12	Zim	371,897	1.7%
13	Hyundai M.M.	347,136	1.6%
14	K Line	341,354	1.6%
15	Wan Hai Lines	229,981	1.1%
16	X-Press Feeders Group	140,723	0.7%
17	KMTC	128,585	0.6%
18	Zhonggu Logistics Corp.	123,836	0.6%
19	Antong Holdings (QASC)	113,364	0.5%
20	SITC	107,010	0.5%
21	IRISL Group	96,383	0.4%
22	Arkas Line / EMES	77,283	0.4%
23	TS Lines	75,484	0.3%
24	Sinotech	67,284	0.3%
25	Sinotrans	62,645	0.3%

Figure 2.8-1: Operational procedure of container terminal, Evaluating Container Terminal Transshipment Operational Policies: An Agent-Based Simulation Approach, Lawrence H

Shipping lines' main objective is to maximize their shipping networks by rationalizing coverage of ports, shipping routes and transit time ((Zohil and Prijon, 1999; Lirn et al., 2004). When focusing on the status of main shipping lines who are dominating in container shipping industry based on market studies it clearly identifies that where the market they perform well and dominate. Maersk Line, MSC and CMA-CGM operate truly global liner service networks, with a strong presence also on secondary routes as well. Especially Maersk Line has created a balanced global coverage of liner services. Especially they are focusing mainly on global transhipment hubs and also, they have their own container terminal network operate by APM terminals. The networks of CMA-CGM and MSC differ from the general scheme of traffic circulation through a network of specific hubs and many of these hubs are not among the world's biggest container ports and a more selective serving of secondary markets such as Africa (strong presence by MSC), the Caribbean and the East Mediterranean. Apart from those main carriers' large number of individual carriers remains regionally based. Asian carriers such as APL, Hanjin, NYK, China Shipping and HMM mainly focus on intra-Asian trade, transpacific trade and the Europe – Far East route, partly because of their huge dependence on export flows generated by the respective Asian home bases. MOL and Evergreen are among the few exceptions frequenting secondary routes such as Africa and South America (Ducruet C., Nottevoom T., 2012). The importance of above analysis is port selection process is specific and unique for each shipping line based on their coverage and area they serve. Here the importance of berth allocation is that since shipping lines has many options and they always focus on the network reliability and hinterland coverage. Due to that, terminal operators should analyse how the main shipping lines behave and their route networks to identify their needs and then only they can cater to their demands especially in berth allocation.

Apart from that it's important to focusing on the alliance structures of main shipping lines since according to the current trend most of shipping lines tend to form alliances to compete with each other as they unable to survive without partners. Not only that as previously discussed some shipping lines are strong in some trading areas while others dominant in another area. With that status if they work together that can achieve more coverage.

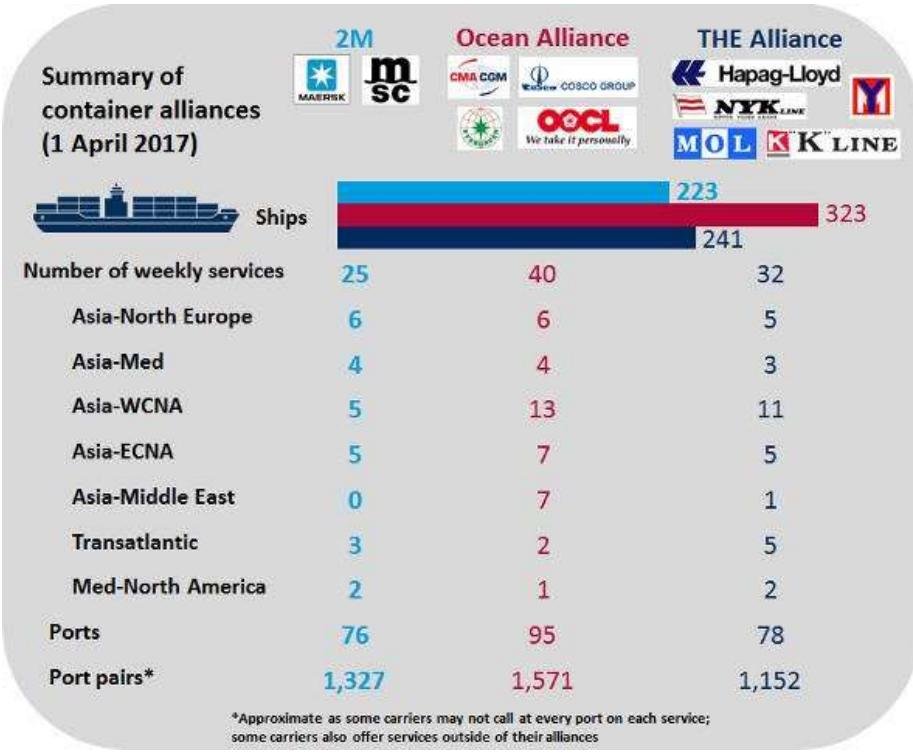


Figure 2.8-2: Summary of Container Alliances, Port Technology, 2017

As shown in figure Maersk Line and MSC line work together in 2M alliance while deploying 223 ships covering approximately 76 ports. Ocean alliance members are CMA CGM, Evergreen, COSCO, and OOCL deploy 323 vessels covering 95 ports. Five main lines including Hapag–Llyod, Yam Ming, NKY, MOL and K-Line represent The Alliance and present in 78 ports deploying 241 vessels. These alliance members also dominate in different regions and it will added advantages when they operate in different routes and ports specially when requesting windows in multi user terminals.

One of the main characteristics which can observe in current container shipping industry is that most of them try to deploy largest vessels in particular routes especially in East Asia – Europe trade. Main reason is that when they are operating in alliances they require larger vessels for consolidation of demand and on the other hand they can deduce the unit cost through economic of scale advantage as well.

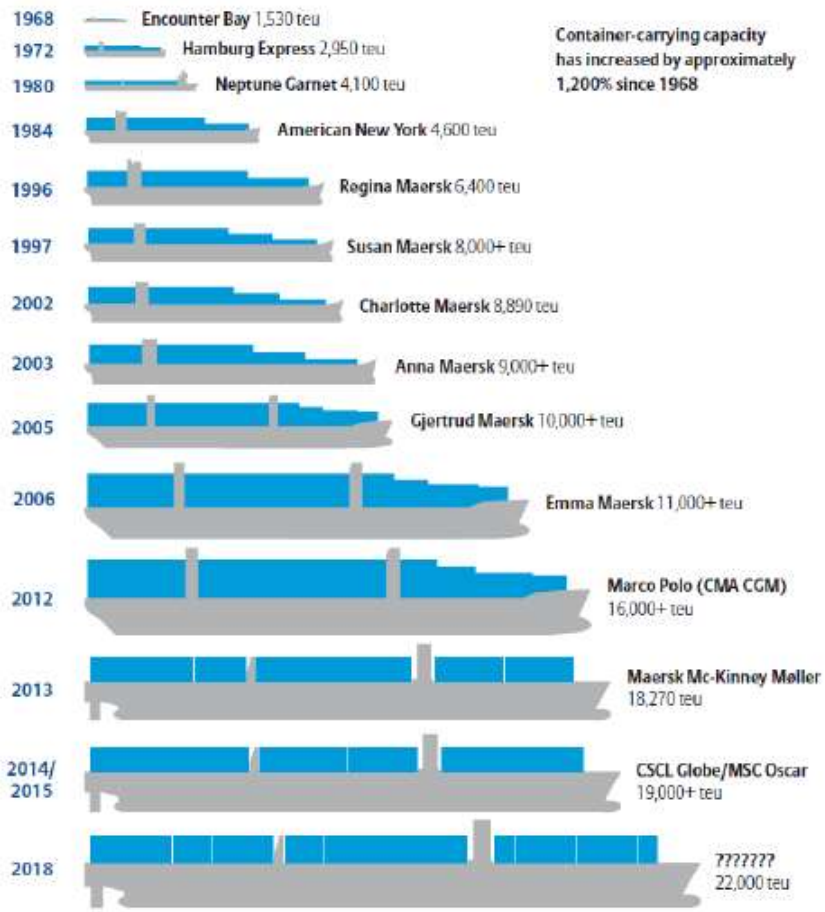


Figure 2.8-3: Fifty years of container Ships growth, Allianz Global corporate & Specialty

2.9 Fleet management in Shipping

When shipping lines design their liner services they have to focus on different areas in macro view.as shown in figure 2.10.1 Trade route analysis, fleet mix selection and port selection processes can identify as main areas they are focusing on. Under the demand profile of trade route there are analysis on existing ports of call. Based on that analysis they move for the identification of possible ports of call at either side of trade route. Under that they analyze the demand profile of ports as flow orientation and geographical specifications, port scale and growth, frequency of ship visits and connectivity. As demand side criteria connectivity consider as most important factor in port selection process and even shipping lines requesting berths in container terminal they mainly focusing on this as well. Under the supply profile of ports focusing on some unique criteria as capacity, cost and quality reliability of nautical access, terminal operations and hinterland access.

Under the market profile of ports focusing on the market structure of port, logistics focus of port and port reputation (Notteboom, 2009). These areas couldn't develop by particular container sea port or terminal overnight and they have to have better service level which maintained over particular period in past. Better service level means good productivity level, minimum waiting time, availability of supportive service etc.

When consider about the strategic, tactical and operational decision levels of container shipping company under strategic category them focusing on areas as market share, port selection, service definition and fleet size and mix. Under tactical level focusing on route/product design, deployment and scheduling while revenue management, empty repositioning and terminal operations consider in operations level (Martin W., 2010). Berth allocation can categorize under strategic level and operational level since shipping lines' port selection decision is depends on many criteria including minimum waiting time in anchorage. On the other hand, berth allocation is routine activity perform by terminal and shipping lines also operates different kind of services and they daily deal with terminals in collaborative manner in this.

Another most important fact is fleet mix of the vessels. Actually, all Shipping lines care about their fleet composition.

2.10 Schedule reliability in container Shipping

Ocean transportation has become a crucial element in organizations' day to day delivery to their customers. Due to this, schedule reliability has become a pivotal element in any organization's service delivery. If ocean liners have a low degree of schedule reliability it can result in significant additional costs. This is not only for their customer but also for the shipping lines and significantly undermines their customers' ability to hold a competitive edge within their respective industries. Reason is that unreliability leads to many issues in supply chain as difficult in resource coordination, increase in safety stocks and impossible to implement just in time/ lean strategies (Chung P., 2007).

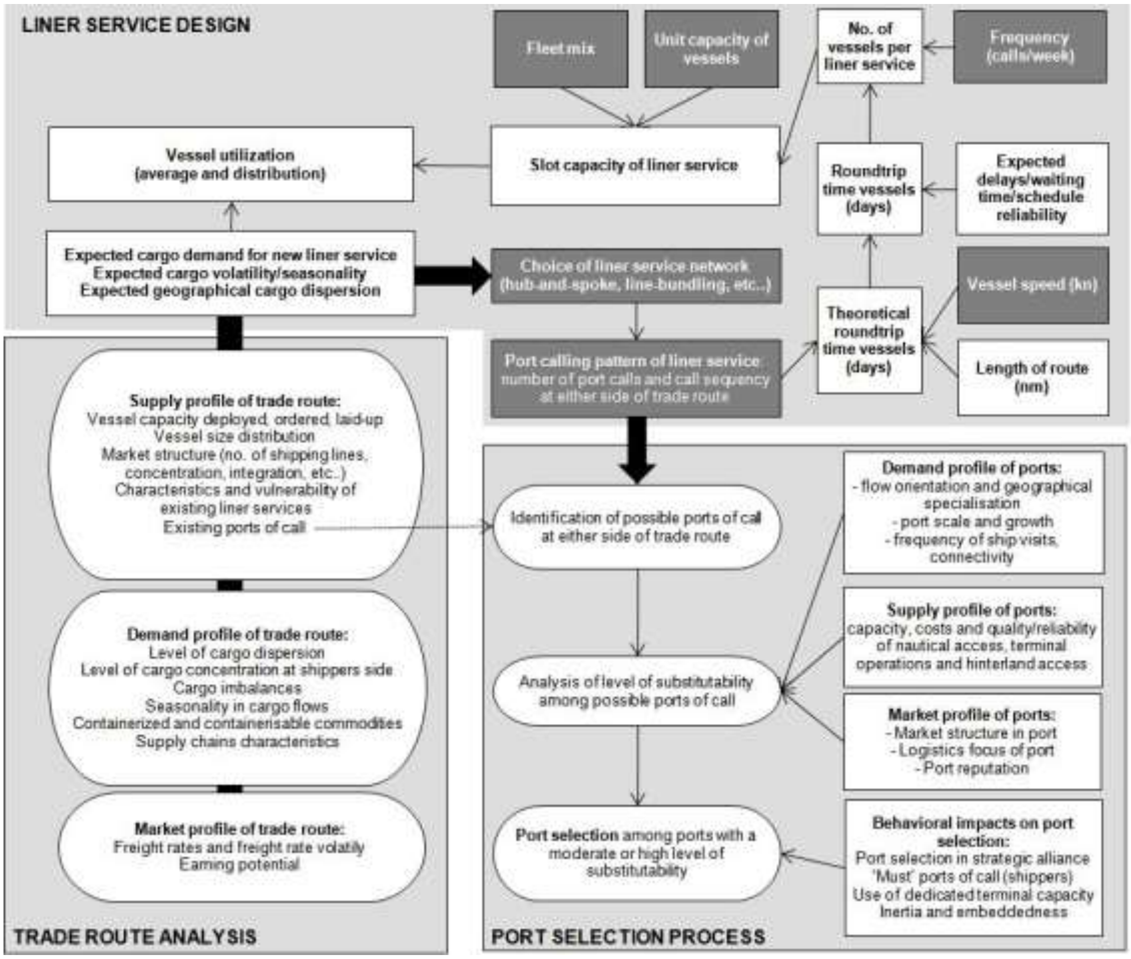


Figure 2.10-1: The process of Liner Service design, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

According to the findings as at July 2017 Hamburg Sud line have identified as a most reliable carrier having 84.4% schedule reliability. Following that APL, Evergreen and HMM also leading in the ranking. But as per the third quarter, 2017 analysis on schedule reliability OOCL line have identified as most reliable carrier having 83.3% schedule reliability level. Evergreen (82.5%), Wan Hai (82.5%), APL (82.3%) and HMM (82%) was among the top reliable carriers (SeaIntel, 2017).

Based on that it can clearly identify the competition among carriers in maintaining schedule reliability to give sophisticated service level to their customers. Port congestion has identified as main factor affecting schedule reliability ((Notteboom, 2006).

In the event where shipping lines faced difficulties in maintaining schedules and when those vessels are running out of schedule they have contingency plan as operational level tactics to implement. Based on the situation they may rearrange the port of call, completely skip the port, employ cut and run tactics, deploy other vessel to take over in combination with a delivery to a hub or increase vessel speed to catch lost time (Notteboom, 2006).

In addition to that it's very much important to focusing on vessel size since it directly affects to the terminal operations. Especially in northern Europe for example, draft restrictions are also an issue if the larger vessels do not arrive on time, because when the tide is at its lowest the largest vessels may not be able to enter to the port. Especially this happens in transshipment ports like Hamburg and Antwerp. Shipping lines are more and more concerning about fleet composition as not every container shipping services use or needs to use very large container ships. Some trades do not have cargo volumes that would justify very large container ships such as in Caribbean trade. Some trades have niches that are well served by smaller, specialized vessels such as in smaller ports in US etc. Even with in hugh volume trades being served by larger vessels, niche services can be served profitable by smaller once (world Shippers Council, 2015).

2.11 Profitability of Container Shipping lines and impact on Berth planning

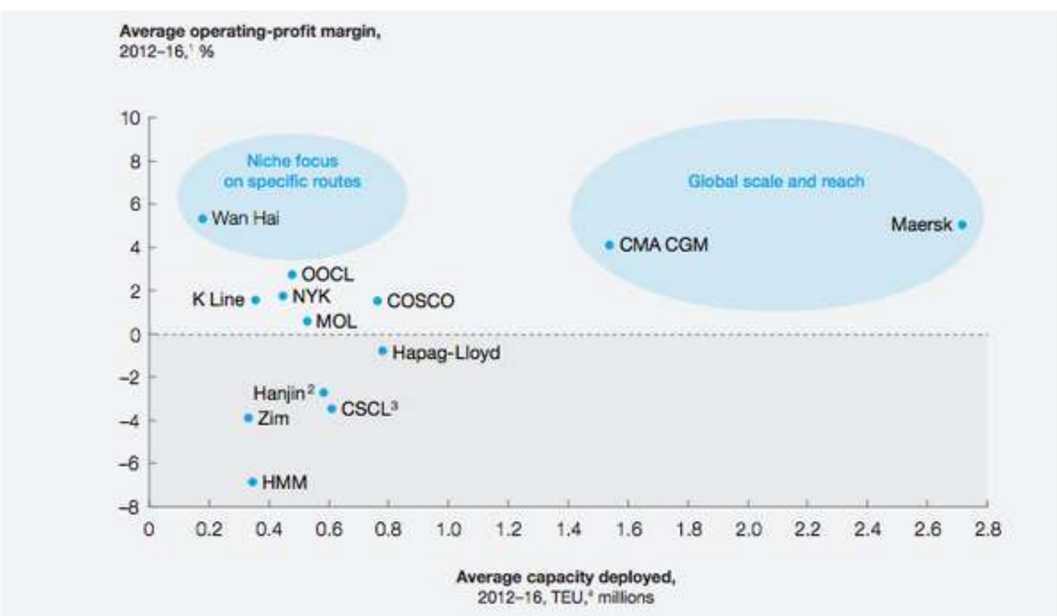


Figure 2.11-1: Operating margins of container carriers, Alphaliner Annual report, McKinsey analysis, 2016

It’s very much important to analyze the profitability of major container carriers since their network efficiency and schedule reliability directly link with that. When particular shipping line make more profits, they may tend to provide better service level to their customers (Alphaliner, 2016).

As shown in above figure no 2.17 It can Cleary identify that WAN HAI, CMA CGM, MAERSK and OOCL lines are at top and in real world scenario they also maintain better level of service reliability as well. In berthing arrangements that always seeking for getting on arrival berths as much as possible to reduce the delays occur at ports.

2.12 The process of Liner service design and its applicability to the berth planning

2.12.1 Configuration of the liner sipping service and networking

Liner shipping networks in container shipping are developed to meet the growing demand in global supply chains in terms of frequency, direct accessibility and transit times. Currently maritime industry container shipping lines are mainly coming under this category where they run their services according to the pre-defined schedule. When increases the demand expansion of traffic has to be covered either by increasing the number of strings operated, or by vessel upsizing, or mix of both (Notteboom, 2009). As such, increased cargo availability has triggered changes in vessel size, liner service schedules and in the structure of liner shipping. When designing their networks, shipping lines implicitly have to make a trade-off between the requirements of the customers and their operational cost considerations (Notteboom, 2009). A higher demand for service segmentation adds to the growing complexity of the networks. From one side Shippers demand direct services between their preferred ports of loading and discharge. The demand side a strong pressure on the service schedules, port rotations and feeder linkages (Notteboom, 2009). Due to this connectivity among vessels berthing arrangements need to do in a way that facilitate to catch the anticipated cargo volume. Shipping lines, however, have to design their liner services and networks in order to optimize ship utilization and benefit the most from scale economies in vessel size. Their objective is to optimize their shipping networks by rationalizing coverage of ports, shipping routes and transit time (Zohil and Prijon, 1999; Lirn et al., 2004). Shipping lines may direct flows along paths that are optimal for the system, with the lowest cost for the entire network being achieved by indirect routing via hubs and the amalgamation of flows.

Bundling can identify as one of the key drivers of container service network dynamics. The bundling of container cargo can take place at two categories as,

(1) Bundling within an individual liner service and

(2) Bundling by combining/linking two or more liner services.

The objective of bundling within an individual liner service is to collect container cargo by calling at various ports along the route instead of focusing on an end-to-end service. Such a line bundling service is conceived as a set of N roundtrips of x vessels each with a similar calling pattern in terms of the order of port calls and time intervals (i.e. frequency) between two consecutive port calls. By the overlay of these N roundtrips, shipping lines can offer a desired calling frequency in each of the ports of call of the loop (Notteboom, 2006). Line bundling operations can be symmetric (i.e. same ports of call for both sailing directions) or asymmetric (i.e. different ports of call on the way back). Most liner services are line bundling itineraries connecting between two and five ports of call scheduled in each of the main markets. The Europe–Far East trade provides a good example. Most mainline operators and alliances running services from the Far East to North Europe stick to line bundling itineraries with direct calls scheduled in each of the main markets. Notwithstanding diversity in calling patterns on the observed routes, carriers select up to five regional ports of call per loop. Shipping lines have significantly increased average vessel sizes deployed on the route from around 4500 TEU in 2000 to over 8000 TEU in early 2011. These scale increases in vessel size have put a downward pressure on the average number of European port calls per loop on the Far East–North Europe trade: 4.9 ports of call in 1989, 3.84 in 1998, 3.77 in October 2000, 3.68 in February 2006, and 3.35 in December 2009. Two extreme forms of line bundling are round-the-world services and pendulum services.

The second possibility is to bundle container cargo by combining/linking two or more liner services. The three main bundling options in this category include a hub-and-spoke network (hub/feeder), interlining and relay. The establishment of global networks has given rise to hub port development at the crossing points of trade lanes. Intermediate hubs emerged since the mid-1990s within many global port systems: Colombo, Salalah (Oman), Tanjung Pelepas (Malaysia), Gioia

Tauro, Algeciras, Taranto, Cagliari, Damietta and Malta (Song, Panayides, 2012). The hubs have a range of common characteristics in terms of nautical accessibility, proximity to main shipping lanes and ownership, in whole or in part, by carriers or multinational terminal operators. Most of these intermediate hubs are located along the global beltway or equatorial round-the-world route (For example the Caribbean, Southeast and East Asia, the Middle East and the Mediterranean). These nodes multiply shipping options and improve connectivity within the network through their pivotal role in regional hub-and-spoke networks and in cargo relay and interlining operations between the carriers' east-west services and other inter- and intra-regional services. Container ports in Northern Europe, North America and mainland China mainly act as gateways to the respective hinterlands (Song, Panayides, 2012).

In channeling gateway and transshipment flows through their shipping networks, container carriers aim for control over key terminals in the network. Decisions on the desired port hierarchy are guided by strategic, commercial and operational considerations. Shipping lines rarely opt for the same port hierarchy in the sense that a terminal can be a regional hub for one shipping line and a secondary feeder port for another operator. For example, Antwerp in Belgium and Valencia in Spain are some of the main European hubs for Mediterranean Shipping Company (MSC) while they receive only few vessels from Maersk Line. Zeebrugge and Algeciras are among the primary European ports of call in the service network of Maersk Line while these container ports are rather insignificant in the network of MSC. For an example MSC line currently handle majority of container throughput in port of Colombo and strive to maintain the status to make Colombo as their transshipment hub (Notteboom, 2012).

2.12.2 The process of designing container liner service

Before a shipping line operator can start with the actual design of a regular container service, they may have to analyses the targeted trade routes. The analysis should include elements related to the supply, demand and market profile of the trade route. Key considerations on the supply side include vessel capacity deployment and unitization, vessel size distribution, the configuration of existing liner services, the existing market structure and the port call patterns of existing operators (Notteboom, 2012). At the demand side, container lines focus on the characteristics of the market to be served, the geographical cargo distribution, seasonality and cargo imbalances. The interaction between demand and supply on the trade route considered results in specific freight rate fluctuations and the overall earning potential on the trade (Notteboom, 2012)..

The ultimate goal of the market analysis is not only to estimate the potential cargo demand for a new liner service, but also to estimate the volatility, geographical dispersion and seasonality of such demand(Notteboom, 2012).. These factors will eventually affect the earning potential of the new service. Once the market potential for a new service has been determined, the service planners need to take decisions on several inter-related core design variables as (1) the liner service type, (2) the number and order of port calls in combination with the actual port selection process, (3) vessel speed, (4) frequency and (5) vessel size and fleet mix.

1) The liner service type

There are major types of liner services and currently some of service types are not in operation due to economic issues in implementation. Under bundling within an individual liner service can identify symmetric and asymmetric liner services. In Symmetric system same ports of call for both sailing directions and in asymmetric different ports of call on the way back. Two extreme service types under this category are round the world service and pendulum service.

Under the category of Bundling by combining/linking two or more liner services there can identify liner service systems as hub and feeder (Hub and Spoke) system, relay system and interlining system.

Figure 2.12-1: Round the World Service, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

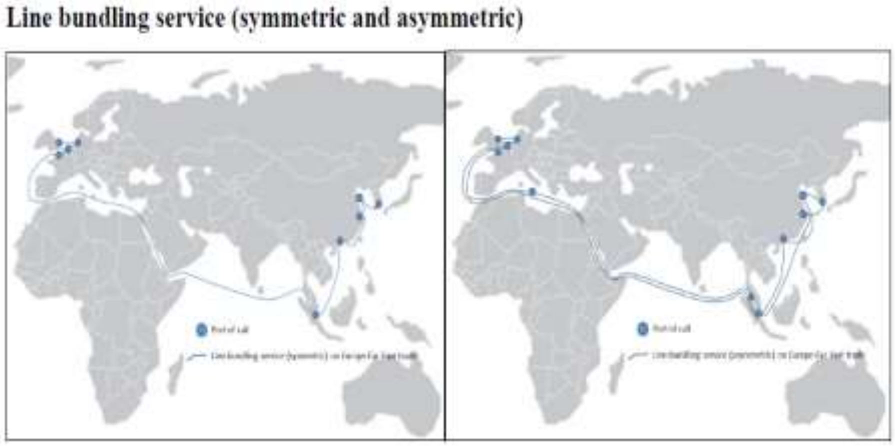


Figure 2.12-2: Line Bundling Service, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

Figure 2.12-3: Pendulum services, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

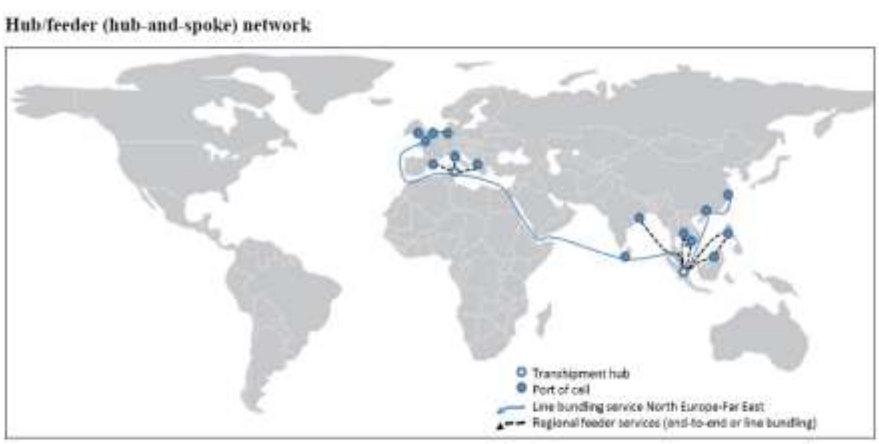


Figure 2.12-4: Hub and Feeder Network, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

Relay

Figure 2.12-5: Relay services, Own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

Interlining

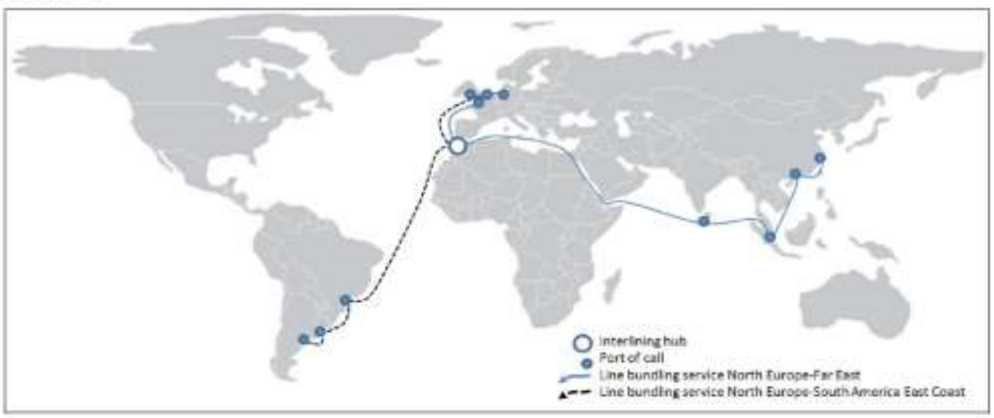


Figure 2.12-6: Interlining services, own elaboration based on insights from Notteboom (2009) and Notteboom and Vernimmen (2009)

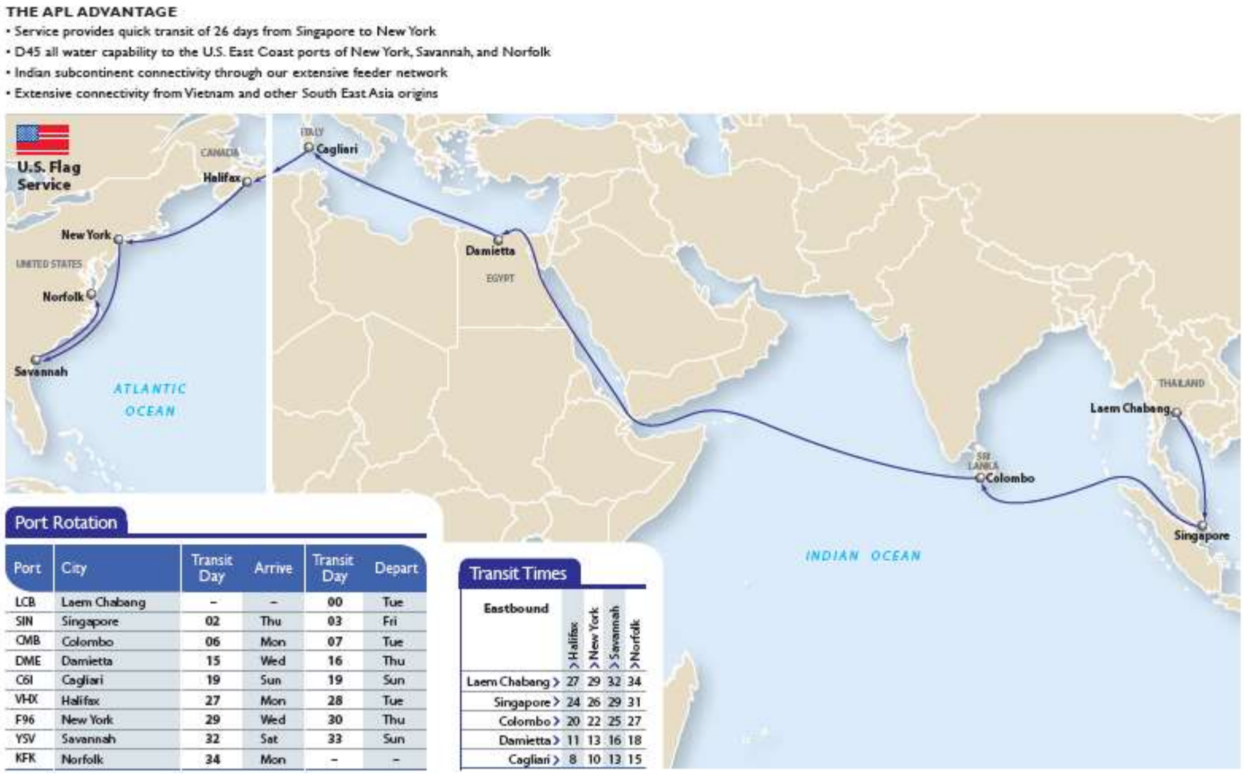
It’s important to discuss how berth allocation affects in above mentioned services. As it can clearly be identified most of the container shipping lines tend to operate asymmetric liner services. Especially in Far East – Europe trade they have this service type. When Shipping lines deploy their vessels in this route, especially in forward leg i.e from Far – east to Europe vessels are full of Full containers. And in reverse leg vessels carry empty containers. In fact, it can celery identify that how much importance the forward leg of their service where cargo need to transport on time to the market. In this case their vessels waiting time should be at minimum level at calling ports. They very much keen on berth allocation since have to follow their sailing schedules as planned and on time. In reverse leg since they are carrying more returned empty containers berth allocation not considered as important as in forward leg.

2) The number and order of port calls in combination with the actual port selection process

As discussed previously there are number of factors consider by shipping lines when selecting the ports of call in their liner services such as Geographical location, Water draft, Feeder connection, Inland intermodal connection, Port reputation, Port dues, Terminal handling charge (THC), Cargo volume, Transshipment cargo volume, Possibility of niche market, Import and export cargo balance and Cargo profitability.

Overall Network cost and port performance are two main factors that have been taken into consideration by container lines selecting ports. In addition container lines consider demand, supply and market profile of the port prior to selection (Notteboom, 2006). Furthermore in some instances Shippers impose bounded rational behavior on shipping lines, for example in case the shipper asks to call at a specific port and those shippers also have mutual relationships with ports and influence power in operations like berthing arrangements as well. On the other hand, port selection by shipping lines can also be influenced by the balance of power among the shipping lines of the same alliance (Wiegmans et al. 2008).

Under the port selection step when shipping lines Limiting the number of port calls its shortens round voyage time and increases the number of round trips per year, thereby minimizing the number of vessels required for that specific liner service. When they are adding port calls can generate additional revenue if the additional costs from added calls are offset by revenue growth. Ports of call mean poorer access to more cargo catchment areas.



Port	City	Transit Day	Arrive	Transit Day	Depart
LCB	Laem Chabang	–	–	00	Tue
SIN	Singapore	02	Thu	03	Fri
CMB	Colombo	06	Mon	07	Tue
DME	Damietta	15	Wed	16	Thu
C6I	Cagliari	19	Sun	19	Sun
VHX	Halifax	27	Mon	28	Tue
F96	New York	29	Wed	30	Thu
YSV	Savannah	32	Sat	33	Sun
KFK	Norfolk	34	Mon	–	–

Eastbound	>Halifax	>New York	>Savannah	>Norfolk
Laem Chabang >	27	29	32	34
Singapore >	24	26	29	31
Colombo >	20	22	25	27
Damietta >	11	13	16	18
Cagliari >	8	10	13	15

Figure 2.12-7: Service in limited no of call, American President Line Official website

In the method of service of limited number of ports, shipping lines are trying to provide fastest service to their shippers by reducing the transit time. In this case ports are facing biggest challenge in berth allocation because these vessels cannot wait in anchorage for awaiting berths. For these clients services need to guaranty the berths on time by giving high priority. Especially this kind of services operate by shipping to cater to the customers who expect fastest transit times irrespective to the cost. And also, the turnaround time of these type vessels comparatively low due to limited volume of cargo of limited number of customers.

In adding ports of call shipping lines plan their services covering many ports and they expect to generate more cargo volume and not much consider about the reliability compared to above scenario with limited number of ports. Due to higher volume port stay time of these vessels considerably higher than in above scenario. Terminal operators have to allocate berths for these vessels from different way since due to longer port stay time and strive to collect more cargo from connecting vessels.

Figure 2.12-8: Service in adding ports of call, Mediterranean Shipping Line Official website

3) Vessel speed

The choice of vessel speed is mainly affected by some factors such as technical specifications of the vessel deployed, the bunker price (Notteboom and Vernimmen, 2009), environmental considerations (e.g. reduction of CO2 through slow steaming) and the capacity situation in the market i.e slow steaming can absorb some of the vessel overcapacity in the market and specially berth availability of approaching terminal. Specially in berthing arrangement berth planners in terminal informed to the responsible officers of shipping lines regarding the berthing arrangements for their vessels. In case if difficult to allocate on arrival berth for vessels terminal instruct particular shipping line to slow down the speed of vessel and on the other way if berths are vacant before the expected time instruct to the shipping lines to speed up their vessels. For an example a mail sent by the terminal to ship line to slow down their incoming vessel to allocate on arrival berth can quote as below.

Quote….

Dear Mr. X (Terminal Berth Planner),

Since our allocated berthing around 29/06-1900hrs @ Berth No -4, vessel will slow down her rpm to berth the vessel on arrival,
In case vessel need to arrive early please do let us know to inform master.
Accordingly, her revised ETA will be 29/06-1800hrs.

R'gds,
Representative – Shipping Line Y

Unquote……

Fuel consumption with the vessel speed can show as below and it can clearly observe that with the vessel speed fuel consumption increases in higher rate.

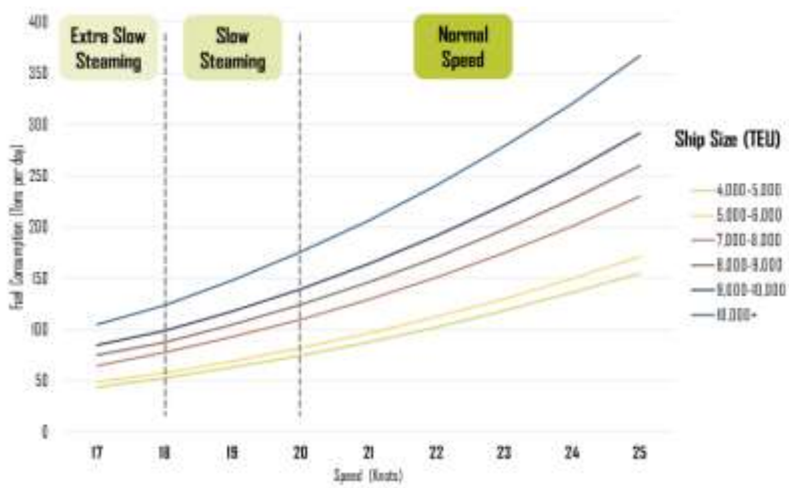


Figure 2.12-9: Fuel consumption with vessel speed, Adapted from Notteboom, T. and P. Carriou (2009) "Fuel surcharge practices of container shipping lines: Is it about cost recovery or revenue making" Proceedings of the 2009 International Association of Maritime Econom

With reference to that, terminal operators must be careful when instruct shipping to increase their vessel speed to allocate early berths since unless there are other advantage due to economically just speeding up is not a favorable decision to shipping line.

4) Frequency

The number and order of port calls, vessel speed and the total two-way sailing distance are the main parameters which determines the total roundtrip time. Theoretically roundtrip time will difficult to achieved in practice due to delays along the route and in ports giving rise to schedule reliability problems. Low schedule integrities can have many causes ranging from weather conditions, delays in the access to ports to port terminal congestion in berthing arrangements. Possibly insert time buffers in the liner service to cope with the chance of delays can be shown as a solution and time buffers reduce schedule unreliability, but increase the vessel roundtrip time

5) Fleet mix and size

The service frequency and the total vessel roundtrip time determine the number of vessels required for the liner service. Carriers have to secure enough vessels to guarantee the desired frequency. Given the number of vessels needed and the anticipated cargo volume for the liner service, the shipping line can then make a decision on the optimal vessel size and fleet mix. As economies of vessel size are more significant on longer distances, the biggest vessels are typically deployed on long and cargo-rich routes. Specially based on the region served shipping line may decide the required vessel size since there are some issues with draft restriction, access channel configurations etc.

As clearly indicate in below figure as decision variable in optimization and scheduling of container liner shipping networks consider number of vessels on route, capacity of vessels, voyage speed, port rotation, containers deployment, fueling and there are some unique constraints also take in to consideration. One of the most important constraint is time window for berthing at the individual ports which is taken in to consideration within this study. It can consider as a most affecting and critical factor in this process as it directly influences to the port selection decision. Practically when shipping lines are planning to commence new service they are asking for berthing windows from each and every port which they have consider and based on the availability they select some ports along the routes where they can carry out required operations.

Figure 2.12-10: Liner planning, optimization and scheduling framework, O links, 2017

2.13 Multi user container (MUT) terminals concept and berth allocation

There is a fundamental difference between a sole or limited-user and a common or multi-user container terminal a sole-user terminal may simply be a component in a vertically integrated operation of container line. Such as a dedicated terminal, which has the financial support and backing of a parent shipping line or group of shipping companies. In contrast, a common, user terminal is frequently a port authority capital venture established to service the regular and often random requirements of a number of shipping lines - the equity risk being borne by the operator of the terminal, not the user who get the services from terminal.

It can clearly observe that over the past years, port related charges in major international hub ports have been increasing rapidly. One of the main reason for this is a relative decrease in handling volume compared to the container terminal capacity by its lease management, resulting in inefficient use of existing capacity. With this type of problematic situation specialists in maritime field was tried to investigate for better operational model to apply in container terminal handling business. As a result of that the use of Multi User Container Terminal (MUT) concept employed in some of the major container hub ports such as Hong Kong, Singapore reduce redundant terminal space and result in substantial cost saving in cargo handling costs. Meanwhile most of the container terminals in china are managed as the Multi User model since the limited terminal space has to be utilize efficiently in order to meet huge container traffic (Brown, 1985).

One of the issue that affects the efficiency of Multi User terminal operators is berth allocation for incoming container vessels to determine their berthing times and positions of vessels (Wang K., 2006).

2.14 Berth allocation practices and trends

First come first served rule (FCFS) rule can identify as an initial method used in allocating berths for vessels in any kind of sea port terminal. A heuristic algorithm was developed considering a first-come-first-served (FCFS) rule. Brown et al. (1994, 1997) treated the BAP in naval ports. They identified the optimal set of vessel-to berth assignments that maximizes the sum of benefits for vessels while in port.

Imai et al. (1997) first introduced the idea that for high port throughput, optimal vessel-to-berth assignments should not be based on the First Come First Served (FCFS) rule. Even they are addressing like that, their formulation may result in some customer’s dissatisfaction regarding order of service. To deal with the two evaluation criteria as berth performance and dissatisfaction due to the order of service, they developed a heuristic algorithm to find a set of non-inferior solutions, while maximizing the former and minimizing the latter. Lim (1998) addressed the continuous BAP with the objective of minimizing the maximum amount of quay space used at any time with the assumption that once a vessel is berthed, it will not be moved to any other place along the quay before it departs. In that case Berthing upon arrival was also assumed. Imai et al. (2006) addressed the berth allocation problem at a multi-user container terminal with indented berths for fast handling. A new integer linear programming formulation was presented, which was then extended to model the berth allocation problem at a terminal with indented berths, where both mega-container vessels and feeder vessels are to be served for higher berth productivity.

Window berthing system introduced to the berth allocation in multi user container terminals since in FCFS system there are many issues faced by shipping lines. Many stevedores have introduced 'berth windows', a guarantee of a berth providing that the vessel operator meets certain performance standards. The aim of berth windows is not only to provide reliability to the stevedore and vessel operator but also to other parties, such as importers, exporters and transport operators. Even though there were anticipated objectives from window berthing system, with that most of carries didn't get anticipated service level form the terminal. Hendrikds M, (2010) Considered a planning problem of a terminal operator who has to construct a cyclic nominal timetable, according to which a set of cyclically arriving vessels is discharged and loaded Disturbances on travel times, however, lead to stochastic arrivals in the port. To cope with these disturbances, the terminal operator and each of the vessel lines agree on a so-called arrival window placed around the nominal arrival times. Only if a vessel arrives within its window, the terminal operator has to process this vessel within the agreed nominal vessel process time. If a vessel arrives outside its window, the terminal operator is not bound to any process time or delaying the schedules.

As analyzed both first come first serves (FCFS) and window berthing arrangements has some issues and multiple criteria should analyze in berth arrangements.

Berth allocation problem is general method in operations research which used in many studies. It deals with the allocation of berth space for container vessels. It can describe as the problem of allocating berthing space for vessels at container terminals and is a critical function of marine container terminal operations. Generally, container vessel arrives over the time and terminal operators need to assign them berths. Shipping lines are always competing for available berths in terminal and also different factors affects the berth and time assignment of each vessel, there are four main Berth allocation problem (BAP) methods which are commonly in use as Discrete Vs. Continuous berthing space, static Vs. Dynamic vessel arrivals, Static Vs. Dynamic vessel handling times and Variable vessel arrivals (Karafa ,2012). In the discrete problem the quay is viewed as a finite set of berths. In the continuous problem, vessels can berth anywhere along the berths. Majority of studies focusing on the discrete case. Within the static arrival problem at the time of scheduling all vessels are already at the port whereas in the dynamic arrival problem only a portion of the vessels to be scheduled are present with arrival time for vessels not present known in advance. In the static handling time problem, vessel handling time considered as input, whereas in dynamic case vessel handling is a variable usually the function of quay cranes that will operate on the vessel and the distance of the vessels' berthing position from the locations in the yard. In the last case which is variable scenario, vessel arrival times are considered as variables and are optimized. In some cases, technical restrictions such as berthing draft and inter vessels and end berth clearance distance are further assumption which are adapted in berth allocation problem. Those additional assumptions bring the problem to real world scenario. As per the Karafa J.(2012) Berth Allocation problem have categorized in to four main areas and most importantly focusing on factors favor to the of container terminal operators and also time factors, equipment positioning, configuration of terminal, productivity levels. Even though from the analysis as output it gives Berth schedule, Quay crane assignment plan and Quay crane assignment plan in generally its favorable to the container terminal operators in day to day operations. Container terminal operators should maintain better relationship with shipping lines in long term specially dealing with berth allocation, because it gains long term benefits to them. The important of this study is that not only focusing on the criteria those were used in BAP but commercial aspects, connectivity and many important areas were considered.

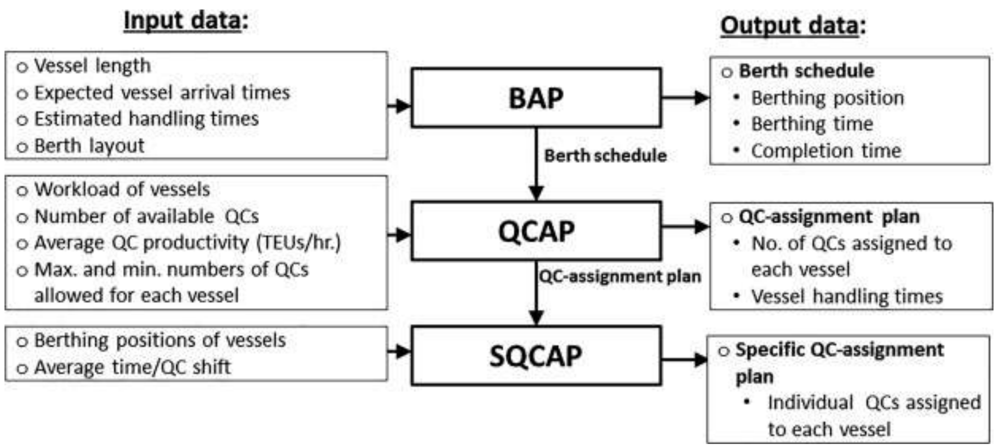


Figure 2.14-1: Integrated Planning of Seaside operations- Berth Allocation Problem, The Container Port Sea Side operation, Athanasios Goltsos, 2015

When formulating a berth allocation problem mainly four types of attributes considered as special attributes (berth layout and water depth and restrictions, temporal attributes (temporal constraints for the service process), handling time attributes (The way vessel handling times are considered) and performance measures which identified as an objective of the optimization problem (Bierwirth, 2015).

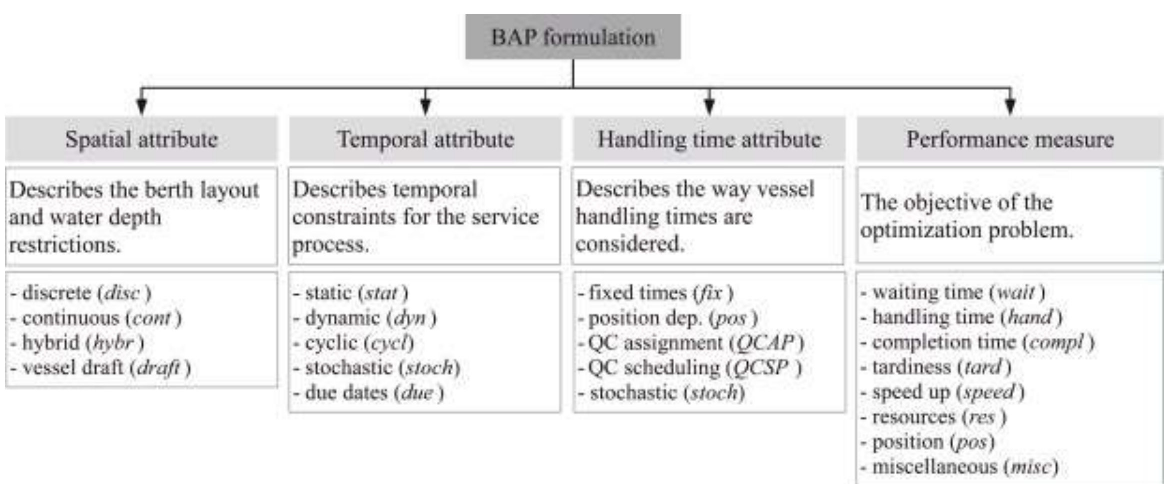


Figure 2.14-2: Formulation of Berth Allocation Problem and attributes consider, A follow-up survey of berth allocation and quay crane scheduling problems in container terminals, Bierwirth,C.

Even though many studies focused and relied on the berth allocation problem in operations research there are no identified studies in the area of berth prioritization using multiple criteria benefited for both container terminal operators and Container lines. There are some vessels operate by particular shipping lines those need to have special prioritization over others due to special reasons. Service priorities and “preferred” berth position for a certain vessel are two issues addressed in some of the BAP published work. Service priorities have been addressed by assigning weights to vessels (Golias, 2010). While several research studies have been done on the allocation of berths proposed the static and dynamic distribution model of the container terminal berths in first time Edmond and Maggs (1978) have used queuing theory model to resolve the allocation of berths and port cargo handling problems. In many studies only, they were focused on limited criteria consider when allocating berths and there is no any research which focused on the multiple criteria covering all the areas have undertaken in berth allocation decision.

It’s more important to focusing on the key performance indicators used to measure the performance of container terminals. Physical indicators are, however, can be considered as one of the most important measures that are applied to evaluating port performance because they reflect the time and processes affecting ships (Holloway, 2010). Therefore, among the most significant indicators to be measured are Ship turnaround time, the average ship waiting time, Cargo dwell time, Productivity per crane-hour, Tons per ship per day. KPIs related to Ship turnaround time and average ship waiting time directly link with the berth allocation procedure.

In fact, today the terminals are under pressure to perform better than ever. Every single stage of supply chain is under pressure financially and that makes turnaround times for vessels critical at the berth. Poor productivity is not tolerable if the terminals want to have long term positions in the market. Especially with the current market condition where time is essential, the introduction of much larger vessels will create a big gap in supply and demand (Kavas, 2016).

2.15 Attributes influence for Berth Allocation problem

As previously discussed The Berth Allocation Problem (BAP) assumes that berth layout of a port is given, along with a set of vessels that are to be served within a considered planned horizon. Each berth in a given port is identified by its unique number, called berth index. Vessels are represented by a set of data, such as their expected arrival time, the size, anticipated handling time, preferred berth in the port, and many others, depending on considered variant of BAP. The ultimate goal of Berth Allocation Problem is to allocate each vessel to a berth index and a time interval so that the given objective function value is optimized.

Under this the objective function(s) can be defined as minimization of the total cost of the allocation, minimization of vessels' waiting times i.e the time that vessels must wait for a berth due to port congestion and handling times (time used for loading/unloading vessels), minimization of earliness and tardiness (lateness of vessels against their desired departure time), minimization of fuel consumption, maximization of profit and maximization of quay cranes (QC) utilization. There are four attributes influence the classification of BAPs: spatial, temporal, handling time, and performance measure.

Table 2.12.2-1: Notations for different types of Berth allocation, Survey Metaheuristic Approaches for the Berth Allocation Problem, Natasa K, 2016

Spatial attribute		**Temporal attribute**		**Handling time attribute**	
Abbreviation	*Attribute*	*Abbreviation*	*Attribute*	*Abbreviation*	*Attribute*
disc	discrete	*stat*	static	*fix*	fixed times
cont	continuous	*dyn*	dynamic	*pos*	position dependent
hybr	hybrid	*cycl*	cyclic	*QCAP*	QC assignment
draft	vessel draft	*stoch*	stochastic	*QCSP*	QC scheduling
		due	due dates	*stoch*	stochastic

2.15.1 Temporal Attribute

The most common BAP models with respect to the temporal attribute are static and dynamic. In the static BAP, the arrival times are either not specified, or they impose soft constraints on the berthing times. Within that approach the first case assumes that vessels are already waiting at the port and can berth immediately. The second case means that a vessel can be speeded up or slowed down at a certain cost. If the arrival times of the vessels are fixed and the vessel cannot berth before the expected arrival time, the corresponding BAP is classified as dynamic. In the case of cyclic BAP, vessels have to be served at terminals repeatedly in fixed time intervals. When vessels arrival times are defined by stochastic parameters and random distribution, BAP is described as stoch. Temporal attribute due is used when the departure of a vessel is influenced by its due date or if a maximum waiting time for the vessel is predetermined before the service starts.

2.15.2 Spatial attribute

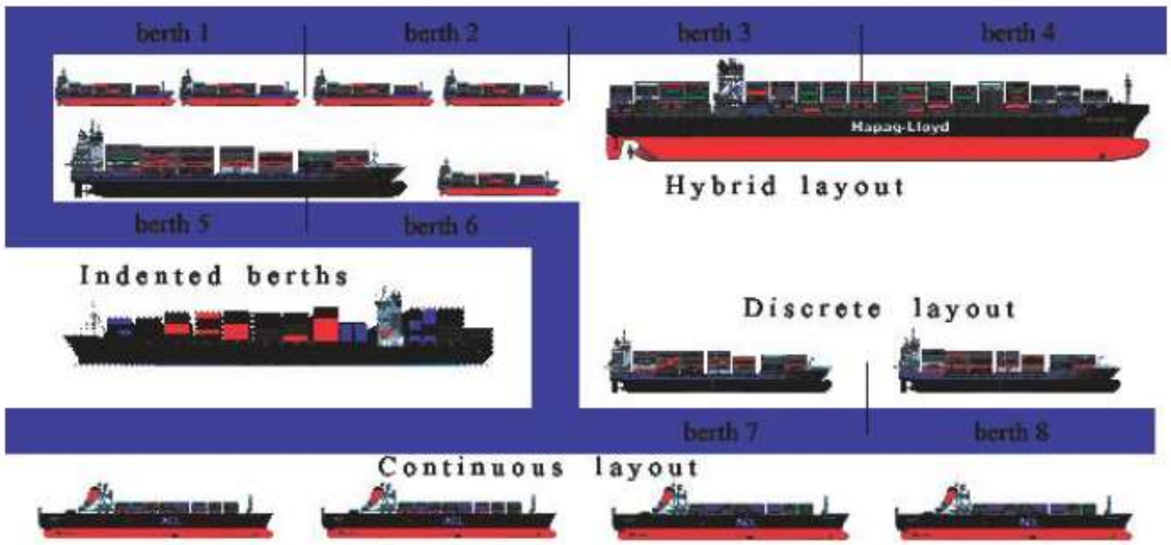


Figure 2.15-1: Variants of Terminal Berthing layouts, Survey Metaheuristic Approaches for the Berth Allocation Problem,Natasa K, 2016

According to the spatial attribute, BAPs can be discrete, continuous, hybrid or draft. In the discrete case, a quay is partitioned into a number of sections - berths, whereas each berth can serve one vessel at a time. In addition, a given time horizon could also be partitioned into discrete units, which enables integer arithmetic for calculating the objective function value. In the continuous case, a calling vessel can be placed at any position if it does not overlap with other vessels' position. Different combinations of discrete and continuous layout in the BAP formulation lead to various types of hybrid layouts. Discrete, continuous, and hybrid layouts, as well as the special case, named indented berth, when quay cranes are enabled to unload and load containers from both sides of the vessel, are illustrated in 2.15.1 Berth Allocation Problem can be classified as draft if vessels' berthing positions are influenced with their draft (Natasa K., 2016).

There are some unique examples can identify under this category of terminal berthing layouts.

Figure 2.15-2: Continuous berthing layouts- Port of Tanjung Pelepas, Malaysia

In continuous type of layouts quay wall considered as strait and any vessels can berth along the quay irrespective to the draft and quay crane specifications as those are same.

Figure 2.15-3: Indented berthing layout, Port of Busan, South Koria

In Indented layouts vessels can berth both sides of the terminal.

Figure 2.15-4: Discrete Berthing Layout

Opposite attribute to continuous layouts where quay wall not a strait and has some bends.

Figure 2.15-5: Hybrid berthing Layout, Jaya Container Terminal, Port of Colombo

Combinations of discrete and continuous layout

2.15.3 Handling time attribute

Based on the handling time attribute, BAPs are classified in five categories: BAPs with fixed handling times, with handling times depending on the berthing position, on the assignment of QCs, on a QC operation schedule, or on stochastic parameters.

2.15.4 Performance measure attribute

This attribute is corresponding to the objective function of a considered BAP. The value of the objective function can depend on waiting time of a vessel, handling time of a vessel, completion time of a vessel, speedup of a vessel to reach the terminal before the expected arrival time, tardiness of a vessel against the given due date, berthing of a vessel apart from its desired berthing position, and some other applicable factors.

In berthing arrangements layout type is consider as most important. In some layouts draft can be different and hence size of the vessel can be berth that particular berths can be different. In some layouts length of the berths can be different and again the size of vessel should take in to consideration. Especially in continues berthing layout the infrastructural attributes of berths (i.e Draft, Length) can be same and also superstructures (i.e Quay crane specifications etc) can be same. But in other types of layouts those can be vary and then shipping lines also target and expect to berth their vessel at particular berths only. In this kind of situation container terminal operators also have to face big issues in berth allocation.

3 Methodology

3.1 Introduction

In this chapter research methodology used in the study is described. The geographical areas where the study was conducted, the study design and the population and sample are described. The instrument used to collect data, including methods implemented to maintain validity and reliability of the instrument are described.

3.2 Research approach & Design

In this study primarily choose a survey research design since it served to answer the questions and the purpose of the study. The survey research is one which a group of people or items is studied by collecting data and analyzing data from only a few people or items considered to be representative of the entire group. In fact, only a part of population is studied by using face to face interviews, teleconferences, questionnaire and findings from the study are expected to be generalized to the entire population (Nworgu, 1991). Based on that within this selected Shipping lines and Container terminals opinion have analyzed and the findings generalized for entire container shipping industry. For analysis mixed approach combining quantitative and qualitative aspects used in this research.

Secondarily literature reviews (Literature based) and articles used to collect relevant data and information which are used to finalize the criteria and analysis as well.

3.3 Selection of population and sample

Within this study population and sampling use when collecting secondary data using questionnaire. Since study supposed to carryout in two aspects as shipping lines perspective and container terminal operator’s perspective population and sampling need to carryout in both areas.

3.3.1 Populating and sample in container terminal operators

As in today maritime industry there are thousands of container terminals in operation covering all the trading areas.

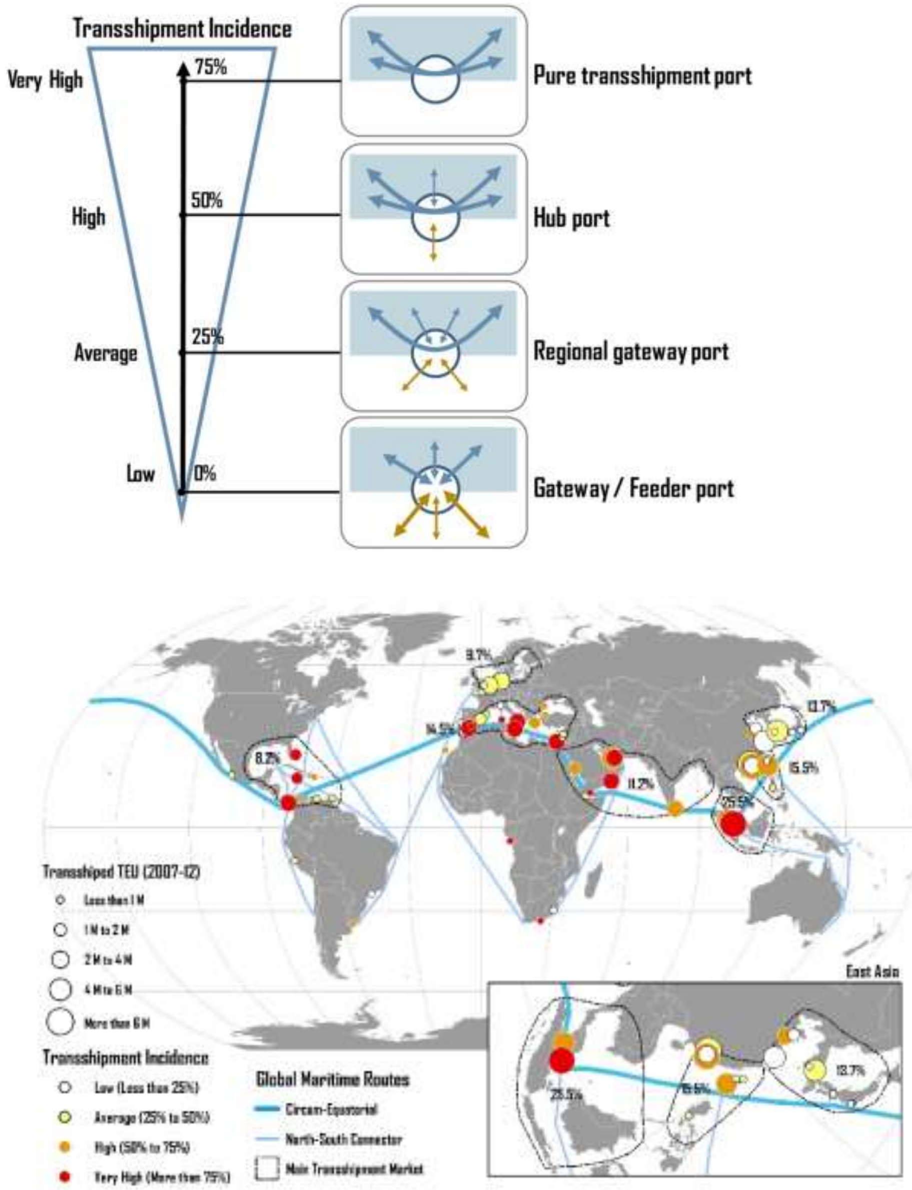


Figure 3.3-1: Transshipment incidence & Major Transshipment ports, Geography of Transport Systems, Hofstra University

As shown in above figure as a population consider main pure transshipment and hub port terminals in world and in sample selection use selected sampling technique where select10 major transshipment container terminals in world. As selection criteria focusing on seven major transshipment areas in world and ranking of world transshipment ports based on volume handled. On the other hand, accessibility for data collection also considered since it's very difficult to connect some terminals for collect data as well.

3.3.2 Population and Sampling in Shipping Lines

Even though there are hundreds of container carries operates in world here also selected 10 major container shipping lines based on their market share hold and ship fleets operates. The reason is that selected 10 carriers currently handle more that 75% in container traffic in maritime transportation.

Figure 3.3-2: The largest container ship Fleets, Alpha liner, 2017

Sample size have reduced to 10 in both aspects to avoid the complexity and errors in analytical hierarchy process and it was also considered as average sample size generally used under this technique.

Based on that ten shipping lines were selected those represent the majority of market share in container shipping.

A.P. Mollar Maersk (Denmark)

Maersk Line is owned by the A.P. Moller–Maersk Group and it is one of the world's largest container shipping company, known for its flexibility, reliability and eco-efficient services. Its head office sits in Copenhagen, Denmark. The company has over 630 vessels with a capacity of 3.3 million TEU. According to recent analysis they manage 19.5% market share in container shipping.

MSC - Mediterranean Shipping Company (Switzerland)

Largest privately-owned shipping company in the world. Currently handle 14.7% market share in container shipping & call at a total of 315 different ports.

CMA – CGM group (France)

CMA CGM Group is the world's third largest shipping company. Call at 420 ports in 160 countries. Current market share is 11.7%.

China Ocean Shipping (Group) Company (COSCO) (China)

Following its takeover of China Shipping Container Lines (CSCL), COSCO is now the world's 4th largest shipping company, the largest shipping company outside of Europe and one of only 4 companies that has a total capacity above 1 million TEU. Market share is 8.4%.

Hapag – Llyod (Germany)

World sixth largest container shipping lines & current market share is 7.2%.

Evergreen Marine (Thaiwan)

World sixth largest container shipping line & currently hold 4.9% market share in container industry.

Orient Overseas Container Line (OOCL) (Hong Kong)

Currently 7th largest container carrier in the world having 3.2% of market share. OOCL has 320 offices in over 70 countries and operates over 300 ships. In addition to shipping the company also operates 2 important Container Terminals: Long Beach Container Terminal, LLC. (LBCT LLC) and Kaohsiung Container Terminal (KAOCT).

Yang Ming Marine Transport Corporation (Japan)

8th largest container carrier in world having 2.7% of market share.

Hamburg Süd Group (Germany)

One of the leading container carrier having fleet of 107 container vessels in operation.

Nippon Yusen Kabushiki Kaisha (NYK Line) (Japan)

10th largest container carrier having market share of 2.6%.

3.4 Data collection

As within this study use primary and secondary data for analysis there are different methods used for data collection. Primary data is one which is collected for the first time by the researcher while secondary data is the data already collected or produced by others.

3.4.1 Primary data sources

Here mainly use interviews and questionnaire to collect relevant data. For finalize the criteria consider by container terminal operators when allocation of available berths for incoming container vessels and to select and finalize the criteria consider by major container shipping lines when requesting available berths in container terminals use primary data which were collected through structured interviews with operational level managers in port of Colombo. After finalizing relevant criteria in both aspects for the analyzing purpose use questionnaire to collect data which prepared in two aspects. One questionnaire sent to the container terminals while another one sent to shipping lines to examine the both aspects.

3.4.2 Secondary data sources

Especially secondary data use in initial stage of the methodology where collecting to data for finalize criteria consider by container terminal operators when allocation of available berths for incoming container vessels and to select and finalize the criteria consider by major container shipping lines when requesting available berths in container terminals. Here use the different documents for collecting data. Including literature surveys, previous studies on berth allocation and container trade, census and articles related to area considered.

3.5 Questionnaire Design

3.5.1 Overview

Using the finalized set of criteria separate two questionnaires have developed to send to Transshipment container terminal operators and main shipping lines. Questionnaires were developed to facilitate to the analytical hierarchy process (AHP) technique. From questionnaire respondent was allowed to compare each criteria and sub criteria and weight those based on their judgment and practical experience. For design questionnaires used data from literature surveys and articles based on berth planning and shipping industry analysis

3.5.2 Structure of the questionnaire

As mentioned two questionnaires were used for collecting primary data collection.

3.5.2.1 Questionnaire to container terminal operators

Main objective of this questionnaire is to collect data which is to measure the opinion of container terminals operators in allocation of berths in their terminals. Finalized criteria included in the questionnaire in the form of which can use in analytical hierarchy process for analytical purpose.

Questionnaire is consisting in three sections as section one for collecting some general data regarding the terminal, section two for comparison of main criteria and section three for comparison of secondary/sub criteria.

3.5.2.2 Questionnaire to Shipping Lines

Main objective of this questionnaire is to collect data which is to measure the opinion of shipping line operators in requesting of berths in container terminals. Finalized criteria included in the questionnaire in the form of which can use in analytical hierarchy process for analytical purpose. Questionnaire is consisting in three sections as section one for collecting some general data regarding the shipping line, section two for comparison of main criteria and section three for comparison of secondary/sub criteria.

3.6 Research Procedure & data analysis

3.6.1 Criteria Development for Container Terminal Operators Aspect in berth allocation

There are set of criteria consider by container terminal operators when allocating berths for incoming container ships. Based on their customer base and number of vessels handled complexity of criteria may change. As inputs used information gathered from literature surveys on berth planning and data collected from interviews had with operations managers in container terminals. Eight main criteria have identified with sub criteria for each one.

3.6.2 Criteria Development for shipping lines' aspect in requesting for Berths

Set of criteria have developed using the data gathered from the interviews had with Main Shipping Lines' operations Managers and from literature surveys, previous studies based on berth allocation. Eight main criteria have identified with sub criteria for each one.

Criteria in both aspects have undertaken in same areas since within this study expected to identify common model which can use for both parties when allocating berths and requesting for berths in container terminals.

3.6.3 Development and Data gathering

As discussed under the topic of “structure of questionnaire” two types of questionnaires use to gather primary data. Questionnaire which designed to collect data from terminal operators directly sent to the operations management level in selected ten container terminals through e mail. Further teleconferences and face to face conversations conduct to give the guidance to fill the questionnaire since comparison and weigh of criteria considered to be quietly complex. Here mainly subject eight criteria compare pairwise and based on the importance they need to weight using likert scale.

Same time another questionnaire sent to the operations management level in ten selected shipping lines who directly involve in vessel operations matters. As same as in above, mainly they need to compare subject eight criteria and weight those using likert scale based on the importance to the berth allocation. Further guidance to fill the questionnaire given through teleconferences.

Since two questionnaires were developed to align with Analytical hierarchy process and its structure collected data directly can imported to the matrix which can identify as an initial step in analytical hierarchy process.

3.7 Data collection through questionnaire and application of Analytical Hierarchy Process (AHP)

3.7.1 Application of analytical hierarchy process

The application of analytical process has to done in two aspects which are from the terminal operators’ perspective and container shipping lines perspective. After conducting under these two aspects for the development of common model again need to conduct the process of analytical hierarchy by combining criteria in two aspects.

Under analytical hierarchy process following steps need to be implement.

1. Define the problem and specify the solution desired. Here problem is to identify the importance of criteria consider by terminal operators when allocating berths for containers vessels and identify the criteria consider by Shipping lines when requesting berths in container terminals. As a solution expect to obtain weight for each criteria and rank those based on importance.

2. Organize the problem as a hierarchy. In doing this, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires. As they work to build the hierarchy, they increase their understanding of the problem, of its context, and of each other's thoughts and feelings about both.

3. Construct a pairwise comparison matrix of the relevant contribution or impact of each element on each governing criterion in the next higher level. In this matrix, pairs of elements are compared with respect to a criterion in the superior level. In comparing two elements most people prefer to give a judgment that indicates the dominance as a whole number. The matrix has one position to enter that number and another to enter its reciprocal. Thus, if one element does not contribute more than another, the other must contribute more than it. This number is entered in the appropriate position in the matrix and its reciprocal is entered in the other position. An element on the left is by convention examined regarding its dominance over an element at the top of the matrix.

3.7.2. Measurements

We cannot draw any conclusions on the hierarchies without any means of measurement. One suitable measurement for AHP is to compare each two elements in the same layer on their relative importance, which is the so called pairwise comparison. The problem after this is that how to measure the relative importance of each two elements. For example, when one considers that factor X is strongly important than factor Y in a layer, he or she can mark 5 when comparing factor X to factor Y.

Intensity of importance	Definition
1	Equal importance
3	Weak importance
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate value between adjacent scale values

Source: Saathy, 1980

The scale comparison provides 9 degrees of comparison outcomes, which of course could be more specific and give more information to researchers. But it also could not be more than 9 degrees because of limits of cognitive capability of human beings which is beyond this paper's discussion.

4. Obtain all judgments required to develop the set of matrices in step 3

5. Multiple judgments can be synthesized by using their geometric mean.

6. Having collected all the pairwise comparison data and entered the reciprocals together with unit entries down the main diagonal, the priorities are obtained and consistency is tested.

7. Perform steps 3, 4, and 5 for all levels and clusters in the hierarchy.

8. Use hierarchical composition (synthesis) to weight the vectors of priorities by the weights of the criteria, and take the sum over all weighted priority entries corresponding to those in the next lower level and so on. The result is an overall priority vector for the lowest level of the hierarchy. If there are several outcomes, their geometric average may be taken. Since within this study use ten participants for each aspect geometric mean of ten participants should obtain.

9. Evaluate consistency for the entire hierarchy by multiplying each consistency index by the priority of the corresponding criterion and adding the products. The result is divided by the same

type of expression using the random consistency index corresponding to the dimensions of each matrix weighted by the priorities as before. The consistency ratio of the hierarchy should be 10 percent or less. If it is not, the quality of information should be improved─ perhaps by revising the manner in which questions are posed to make the pairwise comparisons. If this measure fails to improve consistency, it is likely that the problem has not been accurately structured ─ that is, similar elements have not been grouped under a meaningful criterion. A return to step 2 is then required, although only the problematic parts of the hierarchy may need revision.

Consistency is a crucial problem for pairwise comparisons. When doing pairwise comparisons, if X is more important Y, Y is more importance than Z, everyone knows that X is more important than Z. In this situation there is no consistency problem. But if we consider another situation where a person gives 2 when X compares to Y and 3 when Y compares to Z. Then we can deduce that when X is compared to Z, the scale of importance should be 6 (2 times 3), but the person may give 5 or 7 when he simply only focuses on comparison between X and Z rather than precious comparison 28 outcomes in main criteria analysis. Therefore, inconsistency occurs in this situation. Inconsistency is a violation of proportionality which may or may not entail violation of transitivity. (Saaty, 1980) had an excellent remark on consistency problem. To measure consistency, it need to compare the largest eigenvalue λmax to number of elements n. The closer λmax is to n, the more consistent is the result (Saaty, 1980). A clearer indicator to consistency is the so-called consistency index (C.I.) and consistency ratio (C.R.).

$$CI = \frac{\lambda\text{max} - \text{n}}{n - 1}$$

$$C.R = \frac{CI}{RI}$$

Where R.I. is random index, a modifier to C.I. to adjust the value of C.I. when n changes, R.I. changes accordingly.

n	3	4	5	6	7	8
R.I.	0.58	0.9	1.12	1.24	1.32	1.41
n	9	10	11	12	13	14
R.I.	1.45	1.49	1.51	1.48	1.56	1.57

The value of R.I., Saathy, 1980=

3.8 Development of equation for both aspects

Outcome obtained from analytical hierarchy process use to develop two types of equations as one can use by terminal operators when allocating berths for incoming vessels while other one can use when requesting for berths in container terminals.

By combining both aspects common model can be derived which benefited for both terminal operators and shipping lines. Combined aspect can derive from multiplying both matrixes.

Finding the **product of two matrices** is only possible when the inner dimensions are the same, meaning that the number of columns of the first matrix is equal to the number of rows of the second matrix (Lumen- Matrices and Matrix Operations).

Further one advantage of using matrices is that you can combine the effects of two or more matrices by multiplying them. This means that, to rotate a model and then translate it to some location, we do not need to apply two matrices. Instead, multiply the rotation and translation matrices to produce a composite matrix that contains all of their effects. This process, called *matrix concatenation*, can be written with the following formula.

$$C = M_1 \cdot M_2 \cdot\ M_{n-1} \cdot\ M_n$$

3.9 Application of Analytical Hierarchy Process in this study

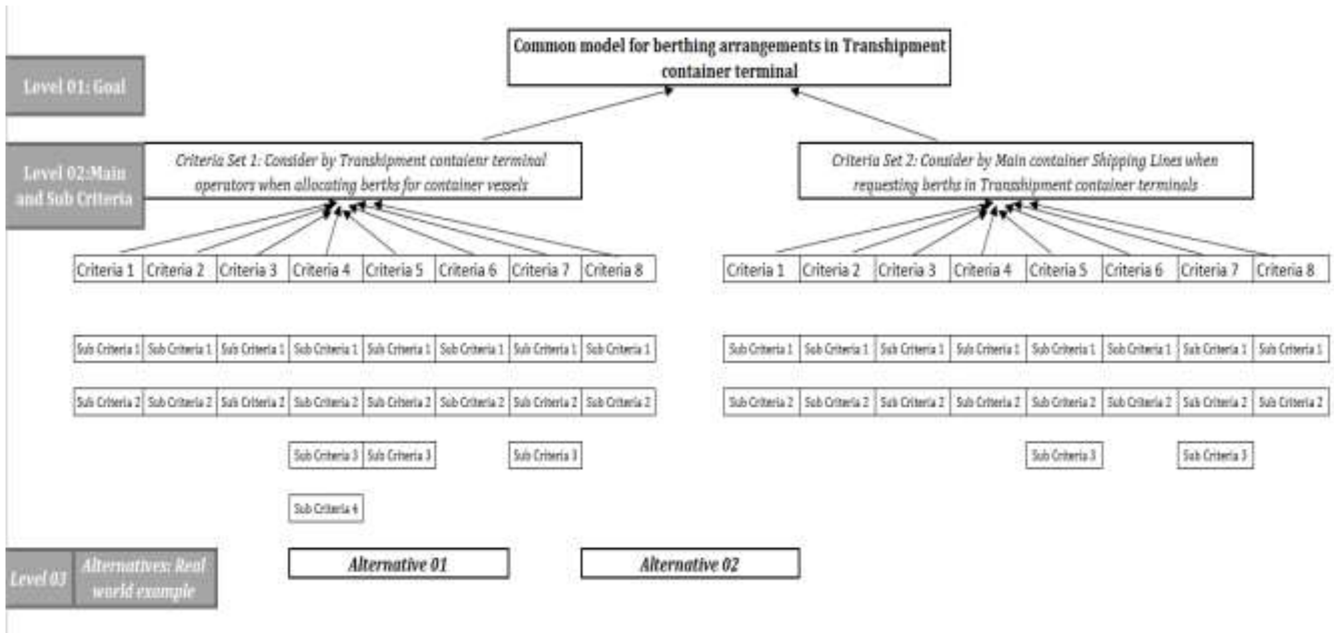


Figure 3-0-1: Application of Analytical Hierarchy Process

3.10 Regression Analysis and Application of the model to real world example

As per the APH model findings; Berth Allocation is influenced by several critical parameters which varies from high importance to low importance and the regression analysis method has been carried out to define the significance of each independent variable to dependent variable of Berth Allocation. Further outcome of AHP analysis in combined aspects have applied to the real-world berthing arrangement problem to be face by container terminal operator.

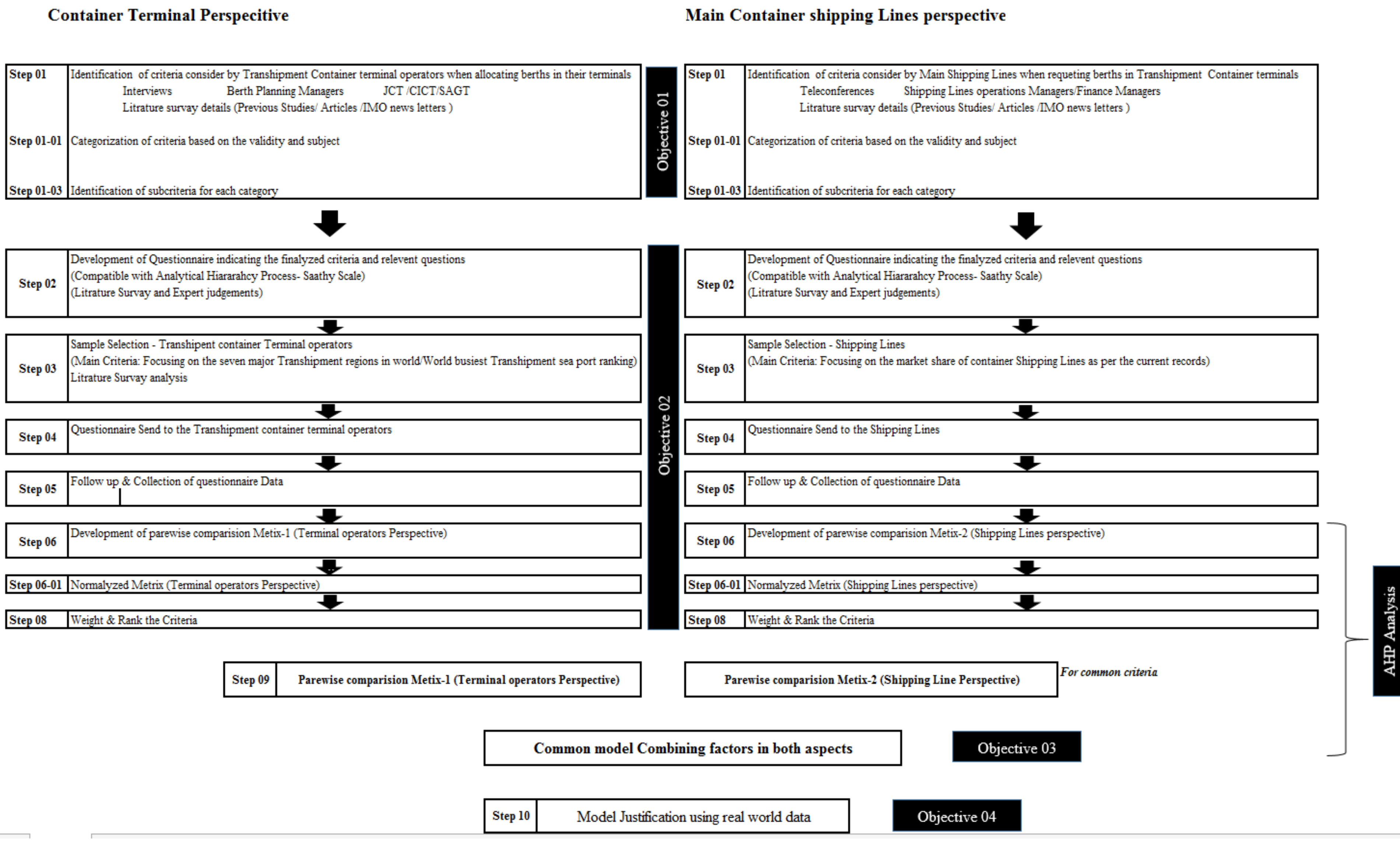


Figure 3.10-1: Research Framework

4 Research Findings

4.1 Introduction

In this chapter, the proposed to analyze the raw data obtained from questionnaires. By putting them into AHP model, three categories of results can be achieved. The first one is priorities of eight criteria consider by container terminal operators when allocating berths for incoming container vessels. Other one is priorities of eight criteria consider by container shipping lines when requesting berths in container terminals. The final result named as win - win model which can use by both terminal operators and shipping lines in arranging berths.

This chapter is organized in the following way. First section presents criteria which were finalized from both aspects. Section two presents and analyzes research results using data have collected for questionnaires by applying analytical hierarchy process (AHP). Under this expect to weight and rank each criterion considered from both aspects.

In third section expect to combine both aspects and develop a common model which benefited for both Shipping lines and transshipment container terminal operators. In fourth section expect to apply the model to real world berthing arrangement example and finally as a fifth section planned to carryout sensitivity analysis.

4.2 Criteria consider by Transshipment container terminal operators when allocating berths for container ships

Eight criteria have been finalized using the data collected from literature surveys regarding berthing arrangements, data collected from the interviews had with operations managers in ports of Colombo and operations managers in considered main shipping lines.

Finalized criteria can illustrate as in table no 4.2.1.

Table 4.2-3.7.1-1: Criteria consider by Transshipment container terminal operators in Berth Allocation

Main Criteria	Sub Criteria
Berthing Pro- forma Schedule	▪ Within the window arrival ▪ Estimated time of Arrival (ETA)
Service agreements & policies	▪ Terminal Service agreements (TSA) between terminal & shipping lines (In case of alliance service, TSA with alliance partners) ▪ Berthing policy of an organization/Terminal
Relationship & Customer service	▪ Bargaining power of the shipping line / Line establishment within industry & competency ▪ Status of the relationship with shipping line
Commercial aspects	▪ Vessel size (Total container volume declared to be handle at the Terminal) ▪ Domestic container volume declared to be handle at Terminal (Import + Export) ▪ Market share growth rate of the particular service where vessel is deploying/operating ▪ Contribution for the revenue of terminal (Percentage of the container volume (TEUs) handle in terminal)
Punctuality of Service	▪ Maintain time schedules (Windows of leading ports and Terminals, Suez, Panama) ▪ Tidal Variations and vessel particulars ▪ Geographical presence & routes operate (East bound - West bound, North Bound-South bound)
Liner Connectivity	▪ Connectivity of the Feeder Network & Main line vessels

	▪ Connectivity of Inter Terminal trucking (ITT) & Export containers (Hinterland connectivity)
Response to the Special requirements	▪ Emergency requirements such as Health problem of crew member, fire on board/ bunkering, on board / hull repairing /fresh water etc ▪ Estimated time of Readiness of the vessel ▪ Readiness of Pre arrival declaration (ISPS, Dangerous cargo, Port Clarence on payments & other relevant documents)
Investment in Terminal (% of Shares ownership)	▪ % of shares hold by shipping line in Terminal ▪ Impact of Global Terminal operators

4.3. Criteria consider by main container shipping lines when requesting for berths in transshipment container terminals

Shipping lines are competing each other based on their own requirements when requesting berths in container terminals. Here also eight criteria have been finalized using the data collected from literature surveys regarding berthing arrangements, data collected from the interviews had with operations managers in ports of Colombo and operations managers in considered main shipping lines.

Table 4.3-3.7.1-1: Criteria consider by main container shipping lines when requesting for berths

Main Criteria	Sub Criteria
Berthing Pro-forma Schedule	▪ Within the window arrival ▪ Estimated time of Arrival (ETA)

Service agreements & policies	▪ Terminal Service agreements (TSA) between terminal & shipping lines (In case of alliance service, TSA with alliance partners) ▪ Berthing policy of an organization/Terminal
Relationship & market power	▪ Bargaining power of shipping line/Alliance ▪ Status of the relationship with terminal
Commercial aspects	▪ Contribution for the revenue of terminal (Percentage of the container volume (TEUs) handle in terminal) ▪ Container volume (including domestic) carrying by the particular vessel (i.e berth requested)
Punctuality of Service	▪ Maintain time schedules (Windows of leading ports and Terminals, Suez, Panama) ▪ Tidal Variations and vessel particulars ▪ Geographical presence & routes operate (East bound - West bound, North bound- South bound)
Liner Connectivity	▪ Connectivity of the Feeder Network & Main line vessels ▪ Connectivity of Inter Terminal trucking (ITT) & Export containers
Special requirements	▪ Emergency requirements such as health problem of crew member, fire on board/ bunkering, on board / hull repairing /fresh water etc ▪ Estimated time of Readiness of the vessel ▪ Readiness of Pre- arrival declaration (ISPS, Dangerous cargo, Port clearance on payments & other relevant documents)
Investment in Terminal (% of Shares ownership)	▪ Return on Investment consideration ▪ Presence as Global Terminal operator

Common criteria were identified regarding this from both aspects and terminal operators and Shipping lines views those from different aspects. From the terminal operators' point of view eight criteria have identified and finalized as Berthing Pro-Forma schedule, Service agreements and policies, Relationship & customer service, Commercial aspects, Punctuality of Service, Liner connectivity, Response to the special requirements and Investment in terminal by shipping line (i.e Shares hold). On the other hand, from the main container shipping lines' perspective eight criteria were finalized and those are as same as in above mentioned criteria and only different is the angle they look at and sub criteria considered. Criteria include Berthing Pro-Forma schedule, Service agreements and schedule, Relationship and market power, Commercial aspects, Punctuality of Service, Liner connectivity, Special requirements and Investment in terminal made by shipping line. Detail information of the subject criteria discuss below form both aspects.

4.3.1. Berthing Pro-forma and schedule

Pro- forma berth, in other word window berthing can identify as a common practice where multi user container terminals use when allocating berths for container ships. When a container terminal has multiples customers (i.e Shipping Lines) to cater there should be slot allocation for each and every vessel deployed for particular services operated by particular shipping line. Within this pro-forma berthing system time slots allocate for each and every service based on availability of berths and to align with their network schedules. In generally Container carriers strive to follow-up their schedules while maintaining better reliability level to deliver cargo on time to their customers. Based on that they develop sailing schedules and pre- define the required berthing and duration of operations time in particular container terminal. To cater to that criteria, they request time slot from selected terminal to berth and operate their vessels deployed in particular service. Duration of time slot depends on the estimated handling volume at the terminal. Under this most important element both parties consider is Estimated Time of Arrival (ETA). After allocating and make an agreement on allocated window terminals are usually bound and give priority to allocate berths to vessels which are calling within that time period. In theoretically when vessels are arrived out of that window terminal operators have to allocate berths to that vessels after assigning available berths to vessels which arrived within window. Sample berthing pro-Forma schedule attached in

Annex No 03. Both Shipping lines and terminals operators consider this tool/criterion in berthing arrangements in different aspects. Especially main shipping lines consider this criterion because they have to maintain their sailing schedules. They may able to follow that if and only they get the opportunity to berth their vessels within window which previously defined.

On the other hand, multi user container terminal operators also have follow up this berthing pro-forma schedule because it considers as one of the major tool use to maximize the rate of berth occupancy in terminal and to satisfy their customer base. Container terminal operators also use this as a tool which use to compete with their competitors. They compare and analyze berthing pro-forma schedules against their competitors to identify the customer base and for looking for the opportunities.

Especially when shipping liens planned to commence new service in particular route prior to terminal selection usually they carry out some preliminary study to check the availability of windows to berth their vessels as scheduled. Sample request illustrate here which denotes how Shipping lines make a request to find out the berthing availability.

Sample request made by shipping line requesting a pro forma window for their liner service can indicate as below.

Quote….

Further to below, as you offered, FRI -0700 hrs to SAT 0700 hrs window is not possible to bring our vessels according to NAVA SHEVA and MUNDRA ports allowable window for XYZ service.

Therefore, our PPL's are requesting us to check with your good terminal and availability for following option with new window requirements.

Kindly check and advice ***on arrival berth facility*** *and other requirements for XYZ service with following window options. (335 M LOA vessels / 3500 moves per caller / 14.10 M draft / 18 across on deck)*

Option A: SAT 18:00 Hrs to SUN 13:00 Hrs.

Option B**: **MON 01:00 Hrs to MON 20:00 Hrs.

***Option C**:*	***SUN 14:00 Hrs to MON 10:00 Hrs.***

New pro-forma requirement for the service named XYZ effective from 2Q of 2018.

Awaiting for your confirmation please.

Unquote…

4.3.2. Service Agreements and Policies

Shipping lines and terminals operators make agreements on their business based on different criteria. TSA includes different criteria those need to focus on when making mutual agreements between shipping lines and terminals. Criteria on terminal handling charges/rates, container volume to be handled in considered period (transshipment/domestic), rebate information etc. Based on that, terminal operator can pre- define how much particular shipping line important to the terminal and level of service to be provide in considered time period. On the other hand, most of the terminals follow their own berthing policy. That policy includes that how vessels should give priority in berthing arrangements. For an example In Chennai port, cargo vessels calling at the port were being berthed generally on the principle of first come first served basis subject to the berthing guidelines/priorities set out by the Government of India from time to time. As per their policy they have underlined specific criteria should consider when allocating berths to incoming vessels as Vessel in distress, Passenger / Cruise vessels, Vessels arriving/sailing with explosives, Coastal vessels, Vessels calling under priority on payment of charges as per Scale of Rates (other than vessels carrying explosives), Containers & Pure Car Carrier Vessels, Vessels berthed that can complete cargo handling operations within 8 hrs.

According to some policies terminals consider home berth concept where line's home berth will always consider first. If home berth not available a berth which can allow immediate operation will be allocated (policy A in table 4.3.2). As per the policy B berth is selected based on earliest departure criteria. In policy C classifies vessels in to three types as Large, Medium and Small. Vessel will be given priority according to its size and assigned a berth (Lai K.K, Shih K, 2010).

Table 4.3.2-1:Characteristics of four allocation policies – Hong Kong International Terminals Ltd, Hong Kong,A Study of container berth allocation, K.K.Lai and Katharine Shih, 2010

	Policy A	***Policy B***	***Policy C***	***Policy D***
Immediate Service Upon Arrival	All	Not All	All	Not All
Earliest Departure	No	All	All if idle berth exists	All L & M vessels All S vessels if idle berth exists
Vessel Priority	No	No	1st L vessel 2nd M vessel 3rd S. vessel	1st L&M vessel 2nd S vessel

As mentioned service policy of terminal and Terminal Service Agreement (TSA) can identify as a one of major criteria which shipping lines and terminal operators consider in berth allocation.

4.3.3. Relationship/ Customer Service and Market power

Today both shipping lines and container terminals are in under pressure due to severe competition in market. Due to that fact both parties tend to work collaboratively to gain mutual benefits and to gain more advantages than their competitors. In this kind of situation terminal operators tend to provide more benefits to shipping lines based on the relationship they have built over time period. On the other side shipping lines also brings more and more services/businesses to the terminal if and only there receive more benefits. Based on that container terminal operators have built up relationships with shipping lines in different levels based on the business and benefits provided. The level of relationship directly affects in berth allocation. Not only that within this criterion both parties consider the period of relationship as well. Usually if particular Shipping line consider as a new customer having potentially good business tend to give better services level including swift berth allocation.

In fact, relationship between container terminal operators and shipping lines can divided in to four categories as shown in below figure.

Figure 4.3-1: Levels of retention strategies, Customer relationship management, Lewis S., 2016

Under financial bonds can consider volume rebate, rate differentiation etc. Under structural bond consider joint investment for equipment /operations etc. Under customization bond can identify innovative services provided, yard allocation, planning aspects etc and under social bond personal relationships developed in managerial level over time can consider.

On the other hand, shipping lines trying to bargain and interfere with terminal regarding berthing arrangements. Especially top three carriers Maersk, MSC and CMA CGM has more power in every route having majority of market share by handling considerably higher volumes of containers in terminals. Based on the market share and market position in the industry they have possibility in making impact on terminals and satisfy their requirements.

As indicate in below Figure no 4.2, can clearly identify how shipping lines dominate in the container business and based on the market share they handle they can make an influence to the terminals they usually call when requesting for berths.

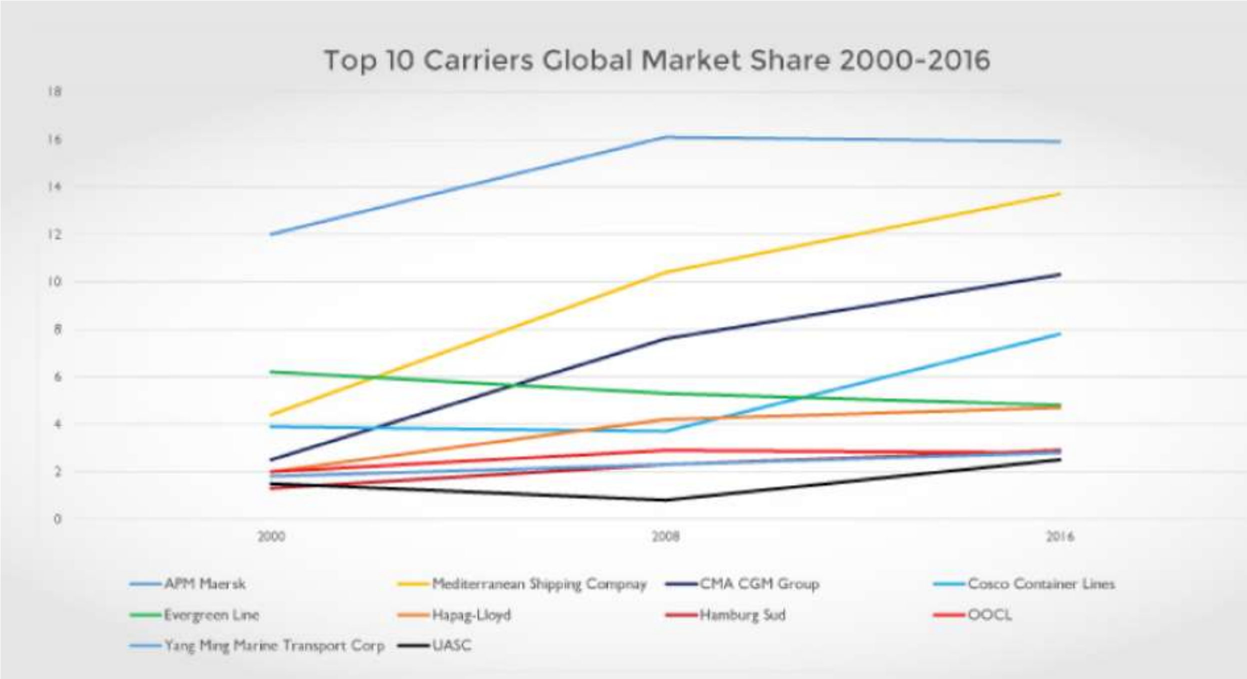


Figure 4.3-2: Top ten carriers' global market share- 2000-2016

When analyze this criteria from both aspects, if it considers from terminal operators' point of view, they are focusing on bargaining power of the shipping line / Line establishment within industry & competency of the shipping lines when negotiating. Also, they have to focus on the status of the relationship with shipping line which can indicate as the relationship which have been build up beyond the professional boundary.

On the other hand, Shipping lines also focusing on some sub factors under this category as their bargaining power (individually or within alliance), and the relationship which has been build up over the time with terminal.

For an example below figure shows that how three main shipping alliances are powerful in two major trade routes.

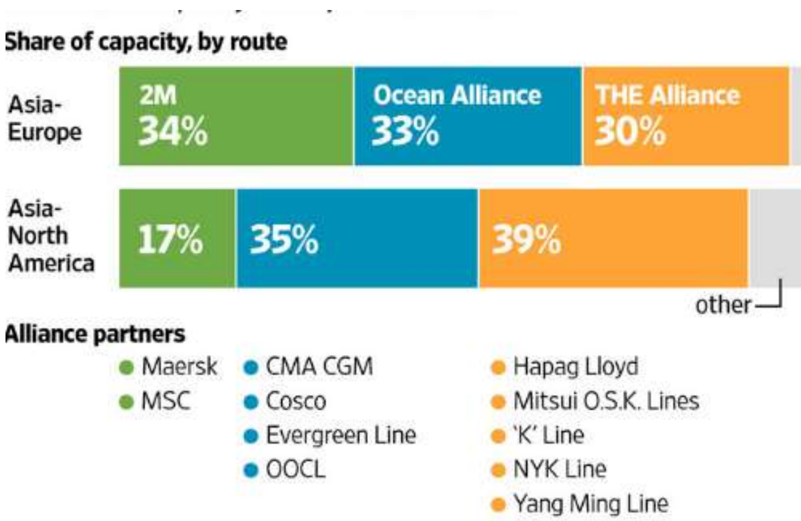


Figure 4.3-3: Share of capacity by route, Alphaliner, 2016

According to above figures it can clearly identify that in Asia –Europe trade three major alliances have severe competition and 2M alliance leading and in Asia- North America trade "the alliance" is more powerful over others. As higher the powerfulness they handle more capacity and have more power in bargaining.

4.3.4. Commercial Aspects

One of the most important criteria where both shipping lines and terminal operators consider when allocating and requesting for berths. First when focusing on the aspect of container terminal operators, as they have multiple shipping lines to serve usually they give priority for shipping lines who contribute to the majority of share from revenue of terminal. In fact, it can say as Contribution for the revenue of terminal (Percentage of the container volume (TEUs) handle in terminal). The more containers handled the more revenue generate. Other than that, also focusing on some sub factors as Domestic container volume declared to be handle at Terminal (Import + Export), Market share growth rate of the particular service where vessel is deploying/operating, Vessel size (Total container volume declared to be handle at the Terminal). Here the more the domestic containers terminal can generate more since the rate of handling domestic containers is higher compared to transshipment units. In some particular markets the business growing rate must be taken in to consideration because in long run it can generate more business to the terminal. As shown in table no 4.4, it can clearly identify that how container business is fluctuating in major trade routes.

Table 4.3.4-1: Container shipping volume (TEU) growth on major trade lanes liked to Asia, Crucial Perspective, 2017

Container shipping volume (TEU) growth on major trade lanes linked to Asia (Jan-Feb 2017)		
Trade lane	**Outbound from Asia**	**Inbound to Asia**
Asia	+29%	+29%
Australasia & Oceania	+4%	+16%
Europe	-1%	+11%
Indian Sub-Continent & Middle East	-3%	+12%
North America	+5%	+9%
South & Central America	+4%	+10%
Sub-Saharan Africa	-20%	+25%

From the point of view of shipping lines, they also consider this criterion when requesting berths in container terminal. They consider the Contribution they have made for the revenue of terminal (Percentage of the container volume (TEUs) handle in terminal) and based on that they can make an impact on terminal authorities when allocating berths. They also consider the container volume carrying by particular vessel which waiting for a berth in terminal and from that they can bargain using that over other awaiting vessel having lower volume compared to that.

4.3.5. Punctuality of Service

Both shipping lines and terminal operators focusing on this criteria in different levels. As shipping lines strive to maintain their schedules they tend to be focusing on this than terminal operators. Both are focusing on some unique sub factors such as Maintain time schedules (Windows of leading ports and Terminals, Suez, Panama), Tidal Variations and vessel particulars and Geographical presence & routes operate (East bound -West bound, North bound- South bound). Especially for the vessels those planned to navigate through Suez and panama windows have to be there on time and if not, they have to wait long time to get another chance. Also, tidal variations are more important in ports having high variations in sea level and having access through river channel. So, based on the tide level vessels need to be on time at port to make an access to the terminal due to draft restrictions.

Simply for the vessels filled with full containers have to give more priority over others since they need to reach to the market on time. Especially west bound ships from China to Europe/America need to give more priority than vessels from west to East filled with more empty containers.

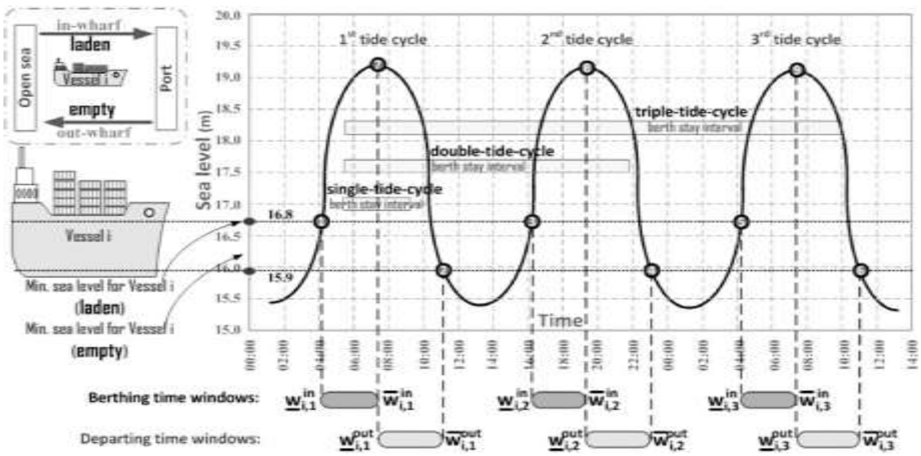


Figure 4.3-4: Sample illustration of Tidal variations in port, Daily berth planning in a tidal port with channel flow, Lu Zhen, 2017

4.3.6. Liner Connectivity

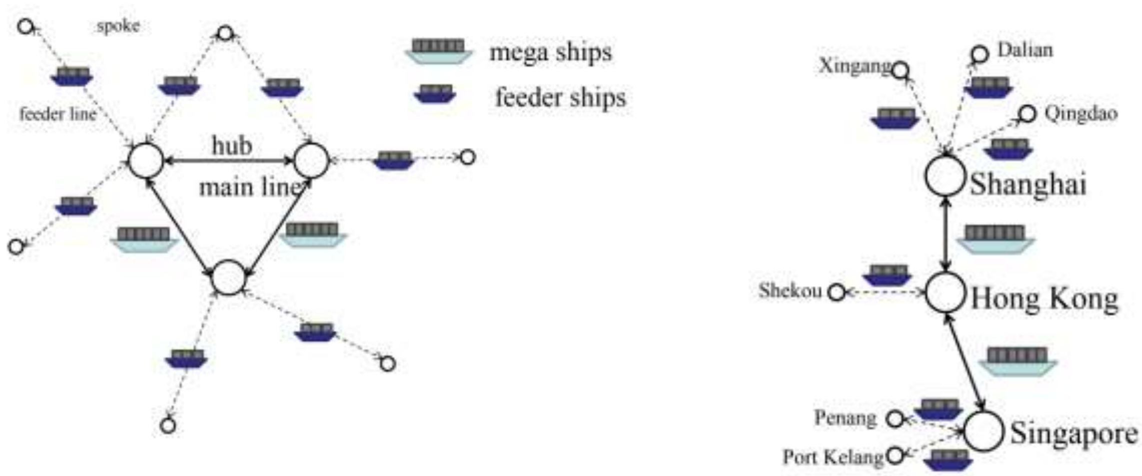


Figure 4.3-5: Main and Feeder Line connectivity in container shipping, Hub and Spoke liner shipping network design, Tingsong W, 2013

Under this criterion consider the connections of containers from other incoming vessels to particular terminals or other terminal in subject port and domestic container volume to be connected to subject vessel. Since shipping lines need to carry anticipated cargo volume, most of the times they tend to wait until the cargo is ready for loading. Terminal operators also consider this criterion because it also generates additional revenue to terminal if vessel able to catch that volume for load on particular vessel. As shown in above figures most of the times feeder lines carry more cargo from small ports and connect to the main line vessels. Also, some main lines carrying cargo from other ports where subject vessel not planned to call. Especially this connectivity happens in hub port where this study focusing on. Sample request quoted below which one shipping lines request delay berth arrangement from terminal to catch the cargo volume from another vessel.

"Reference teleconference, kindly note that MV XXXX having 180 TEUS (18 x 20') connection from X terminal vessel MV……….. (ETB – 29/1800 hrs) and 96 TEUS (3 x 40') connection from Y terminal vessel MV………. (ETB – 30/0001 hrs).
Accordingly, hereby request you to berth MV. XXXX after today mid night in order to fulfill the above connection. (Due to subject vessel Performa is on Saturday 0500 hrs.)

As MV.XXXX is going to berth early to her Performa and in case she will idle at berth to fulfill the said connection (24 TEUS), request to waive off any idling charges accordingly.

We are pushing X & Y terminals to truck the said boxes to your terminal ASAP, to carry out the cargo operation without any obstructions.

Your kindly assistance will be much appreciated in this regard"

As per the above request vessel named XXXX request delay berth at terminal to catch the cargo volume from two vessels planned to berth at X and Y terminals in same port.

4.3.7. Response to special requirements

In some instances, Shipping lines make special requirements from terminal and terminal operators should consider those when allocating berth for subject vessels. Under this there are some requirements should consider such as Health problem of crew member, fire on board/ bunkering, on board / hull repairing /fresh water, readiness of Pre- arrival declaration (ISPS, Dangerous cargo, Port Clarence on payments & other relevant documents) etc. with those requirements some instances they require immediate berths and in some instances request delay berths. Sample mail received from shipping line indicating the requirements can show as below.

"*Further to below update given regarding ETA & Load move count, please be good enough to allocate a suitable berth to fulfill following requirements during her port stay.*

++Quote++

Pls arrange at port Colombo:
01. Fresh water supply 50 mt.
02. Immobilization for 04hours.
03. Port side alongside
04. By Charterer order Bunker: ***HFO 100 mt.***

By owner:-
01. Bonded Stores,
02.Ship's supply
03.Ship's spare parts

++ Un Quote++

4.3.8. Investment in Terminal

Some Shipping lines are currently involving in terminal operations and some are investing in terminal operate by other parties. Container shipping lines have become major players in the container terminal market by entering key ports, using shareholdings, joint ventures with local or global terminal operators, sister companies or subsidiaries focused on terminal operations. From the container terminal point of view if particular shipping line have shares in terminal usually they have authority in bargaining priority berths over others. This is solely depending on the agreement between shipping line and terminal signed when investing in infrastructure or superstructure.

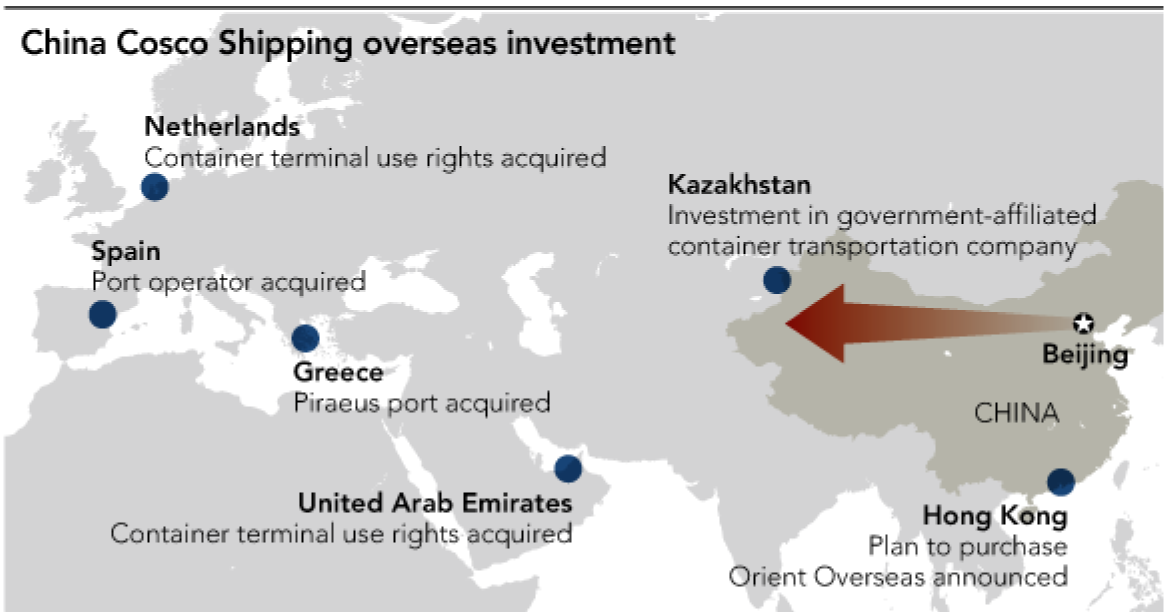


Figure 4.3-6Overseas investment in terminal by COSCO line, china, Cosco Line official website

On the other hand, some shipping lines are representing as global terminal operators and since based on that they also can make an impact on other terminals when requiting berths. According to current data PSA remained in first place with 56,300,000 teu, growing 6%, Hutchinson Ports also maintained second place but with a 3% dip in growth, followed by **APM Terminals** also staying at number three with a 3% growth. DP World was fourth, keeping its rank but with zero growth, **Cosco Shipping** Ports also stayed at number five with a 4% growth. It can realize that Maersk Line and COSCO line are among the best five container terminal operators in world and they can make impact on terminals when requesting berths since if not they able to divert their vessel to owned terminals even it consider as a decision involve more cost.

Table 4-5: Forecast Global/International container terminal operator capacity ranking, 2020, Drewry Maritime research, 2017

Operator	Capacity rank	
	2020	Current
Cosco-China Shipping	1st	4th and 8th
APM Terminals *	2nd	2nd
PSA International	3rd	3rd
Hutchison Port Holdings	4th	1st
DP World	5th	5th
Terminal Investment Ltd	6th	6th
CMA CGM **	7th	9th

* Grup TCB included in 2020 ranking calculations

** APL included in 2020 ranking calculations

Calculations are based on the total capacity for all terminals (regardless of size of shareholding) and do not include the capacity of other operators in which minority stakes are held.

4.4 AHP Results Presentation

4.4.1 Analysis of the Container Terminal operators' perspective

4.4.1.1 Analysis of the Main criteria consider by container terminal operators when allocating Berths for main line container vessels

Pairwise comparison matrix has developed using questionnaire data collected from ten respondents i.e ten transshipment container terminal operators. Here all Transshipment container terminal operators' goal is to allocate berths to incoming vessels in their container terminal hence they behave like one and since the group becomes a new individual and behaves like one, the reciprocity requirement for the judgments must be satisfied and the geometric mean rather than an arithmetic mean must be used. When individuals are each acting in his or her own right, with different value systems, we are concerned about each individual's resulting alternative priorities. An aggregation of each individual's resulting priorities can be computed using either a geometric or arithmetic mean (Adamcsek, 2008).

Table 4.4.1.1-1: Pairwise Comparison Matrix for the aggregated responds of Terminal operators (M1)

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Customer service	Commercial aspects	Punctuality of Service	Liner Connectivity	Response to Special Requirements	Investment in Terminal
Berthing Pro-Forma	1.0000	4.7452	4.0055	2.0345	4.9939	3.6165	4.8287	0.8448
Service Agreements & policies	0.2107	1.0000	1.4746	0.2717	2.1788	1.5518	3.1090	0.3010
Customer service	0.2497	0.6782	1.0000	0.2860	1.9332	2.0345	4.4364	0.3333
Commercial aspects	0.4915	3.6801	3.4968	1.0000	3.0578	2.2533	4.8287	1.4011
Punctuality of Service	0.2002	0.4590	0.5173	0.3270	1.0000	0.4915	3.3227	0.4915
Liner Connectivity	0.2765	0.6444	0.4915	0.4438	2.0345	1.0000	3.3227	0.3167
Special Requirements	0.2071	0.3216	0.2254	0.2071	0.3010	0.3010	1.0000	0.2215
Investment in Terminal	1.1837	3.3227	3.0000	0.7137	2.0345	3.1572	4.5144	1.0000
sum	**3.8195**	**14.8512**	**14.2111**	**5.2838**	**17.5336**	**14.4059**	**29.3625**	**4.9100**

Table 4.4.1.1-2: Normalized Matrix for the aggregated responds of Terminal operators'

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Customer service	Commercial aspects	Punctuality of Service	Liner Connectivity	Response to the Special Requirements	Investment in Terminal	Average
Berthing Pro-Forma	0.2618	0.3195	0.2819	0.3850	0.2848	0.2510	0.1644	0.1721	0.2651
Service Agreements & policies	0.0552	0.0673	0.1038	0.0514	0.1243	0.1077	0.1059	0.0613	0.0846
Customer service	0.0654	0.0457	0.0704	0.0541	0.1103	0.1077	0.1511	0.0679	0.0841
Commercial aspects	0.1287	0.2478	0.2461	0.1893	0.1744	0.1564	0.1644	0.2854	0.1991
Punctuality of Service	0.0524	0.0309	0.0364	0.0619	0.0570	0.0341	0.1132	0.1001	0.0608
Liner Connectivity	0.0724	0.0434	0.0346	0.0840	0.1160	0.0694	0.1132	0.0645	0.0747
Response to the Special Requirements	0.0542	0.0217	0.0159	0.0392	0.0172	0.0209	0.0341	0.0451	0.0310
Investment in Terminal	0.3099	0.2237	0.2111	0.1351	0.1160	0.2192	0.1537	0.2037	0.1966

Table 4.4.1.1-3: Relative Weights for criteria consider by container terminal operators when allocating berths

Berth Requesting Criteria	Average	Rank
Berthing Pro-Forma	0.2651	1
Service Agreements & policies	0.0846	4
Customer service	0.0841	5
Commercial aspects	0.1991	2
Punctuality of Service	0.0608	7
Liner Connectivity	0.0747	6
Response to the Special Requirements	0.0310	8
Investment in Terminal	0.1966	3

Berthing Pro- Forma was ranked as a most important criteria and Commercial aspects ranked as second most important.

Consistency Analysis

This step is carryout in order to measure the consistency of response in pairwise comparison.

ƛ max	8.4961	
CI, when No of comparisons, n is equal to 8	CI= (ƛ max-1)/(n-1)	(8.49613078379427-1)/ (8-1) =0.0708
CR	CR= CI/RI	RI=1.41 (For n=8)
CR	**0.050** < 0.1	

Since CR value is less than 0.l and result is acceptable.

4.4.1.2. Analysis of the Sub criteria under each main criterion consider by container terminal operators when allocating Berths for main line container vessels

Main Criteria: Commercial Aspects

Table 4.4.1.2-1: Pair wise comparison matrix for sub criteria under "Commercial aspects"

Main Criteria: Commercial Aspects	Vessel Size (Total containers to be handle)	Domestic container volume	Market share growth rate	Contribution for the revenue of terminal
Vessel Size (Total containers to be handle)	**1.0000**	**2.9770**	**4.2154**	**0.2107**
Domestic container volume	**0.3359**	**1.0000**	**3.6801**	**0.2294**
Market share growth rate	**0.2372**	**0.2717**	**1.0000**	**0.1840**
Contribution for the revenue of terminal	**4.7452**	**4.3597**	**5.4355**	**1.0000**
Sum	6.3183	8.6084	14.3310	1.6241

Table 4.4.1.2-2: Normalized matrix for sub criteria under "Commercial aspects"

Main Criteria: Commercial Aspects	Vessel Size (Total containers to be handle)	Domestic container volume	Market share growth rate	Contribution for the revenue of terminal
Vessel Size (Total containers to be handle)	**0.1583**	**0.3458**	**0.2941**	**0.1298**
Domestic container volume	**0.0532**	**0.1162**	**0.2568**	**0.1412**
Market share growth rate	**0.0375**	**0.0316**	**0.0698**	**0.1133**
Contribution for the revenue of terminal	**0.7510**	**0.5064**	**0.3793**	**0.6157**

Table 4.4.1.2-3: Relative Weights for sub criteria under main criteria – Commercial aspects:

Main Criteria: Commercial Aspects	Average	Rank
Vessel Size (Total containers to be handle)	0.2320	2
Domestic container volume	0.1418	3
Market share growth rate	0.0630	4
Contribution for the revenue of terminal	0.5631	1

Contribution for the revenue of terminal considered as most important sub criteria.

Main Criteria: Punctuality of Service

Table 4.4.1.2-4: Pair wise comparison matrix for sub criteria under "Punctuality of Service"

Main Criteria: Punctuality of Service	Maintaining time schedules	Tidal variations & vessel particulars	Geographical Presence & routes operate
Maintaining time schedules	1.0000	0.2860	3.6801
Tidal variations & vessel particulars	3.4968	1.0000	4.7452
Geographical Presence & routes operate	0.2717	0.2107	1.0000
Sum	4.7686	1.4967	9.4253

Table 4.4.1.2-5: Normalized matrix for sub criteria under "Punctuality of Service"

Main Criteria: Punctuality of Service	Maintaining time schedules	Tidal variations & vessel particulars	Geographical Presence & routes operate
Maintaining time schedules	0.2097	0.1911	0.3905
Tidal variations & vessel particulars	0.7333	0.6681	0.5035
Geographical Presence & routes operate	0.0570	0.1408	0.1061

Table 4.4.1.2-6: Relative Weights for sub criteria under main criteria – Punctuality of Service

Main Criteria: Punctuality of Service	Rank
Maintaining time schedules	2
Tidal variations & vessel particulars	1
Geographical Presence & routes operate	3

Tidal variations and vessel particulars considered as most important sub criteria.

Main Criteria: Response to the Special requirements

Table 4.4.1.2-7: Pair wise comparison matrix for sub criteria under "Response to the special requirements"

Main Criteria: Response to the Special	Emergency requirements	Estimated time of readiness	Readiness of Pre Arrival declaration
Emergency requirements	**1.0000**	**0.3167**	**0.2582**
Estimated time of readiness	**3.1572**	**1.0000**	**2.9770**
Readiness of Pre Arrival declaration	**3.8730**	**0.3359**	**1.0000**
Sum	8.0302	1.6526	4.2352

Table 4.4.1.2-8: Normalized matrix for sub criteria under "Response to the special requirements"

Main Criteria: Response to the Special requirements	Emergency requirements	Estimated time of readiness	Readiness of Pre Arrival declaration
Emergency requirements	**0.1245**	**0.1917**	**0.0610**
Estimated time of readiness	**0.3932**	**0.6051**	**0.7029**
Readiness of Pre Arrival declaration	**0.4823**	**0.2033**	**0.2361**

Table 4.4.1.2-9: Relative Weights for sub criteria under main criteria – Response to Special requirements

Main Criteria: Response to the Special requirements	Average	Rank
Emergency requirements	0.1257	3
Estimated time of readiness	0.5671	1
Readiness of Pre Arrival declaration	0.3072	2

Estimated time of readiness i.e. vessel readiness time given by vessel operator consider as most important sub criteria.

Main Criteria: Berthing Pro-Forma

Table 4.4.1.2-10: Pair wise comparison matrix for sub criteria under main criteria berthing Pro- Forma

Main Criteria: Berthing Pro-Forma	Window Arrival	ETA
Window Arrival	1.0000	3.0000
ETA	0.3333	1.0000
sum	1.3333	4.0000

Table 4.4.1.2-11: Normalized matrix for sub criteria under main criteria berthing Pro- Forma

Main Criteria: Berthing Pro-Forma	Window Arrival	ETA	Average
Window Arrival	0.7500	0.7500	0.7500
ETA	0.2500	0.2500	0.2500

Table 4.4.1.2-12: Relative Weights for sub criteria under main criteria- Berthing Pro- Forma

Main Criteria: Berthing Pro-Forma	Average	Rank
Window Arrival	0.75	1
ETA	0.25	2

Main Criteria: Service Agreements & Policies

Table 4.4.1.2-13: Pairwise comparison matrix for sub criteria under "Service agreements and policies

Main Criteria: Service Agreements & Policies	Terminal service Agreements (TSA)	Berthing policy of Terminal
Terminal service Agreements (TSA)	1.0000	1.8228
Berthing policy of Terminal	0.5486	1.0000
sum	1.5486	2.8228

Table 4.4.1.2-14: Normalized matrix for sub criteria under "Service agreements and policies"

Main Criteria: Service Agreements & Policies	Terminal service Agreements (TSA)	Berthing policy of Terminal
Terminal service Agreements (TSA)	0.6457	0.6457
Berthing policy of Terminal	0.3543	0.3543

Table 4.4.1.2-15: Relative Weights for sub criteria under main criteria – Service agreements and policies

Main Criteria: Service Agreements & Policies	Average	Rank
Terminal service Agreements (TSA)	0.6457	1
Berthing policy of Terminal	0.3543	2

Terminal service agreements considered as most important criteria.

Main Criteria: Customer Service

Table 4.4.1.2-16: Pairwise comparison matrix for sub criteria under "Customer service"

Main Criteria: Customer Service	Shipping Line's establishment in industry	Status of relationship with Terminal
Shipping Line's establishment in industry	1.0000	0.2453
Status of relationship with Terminal	4.0760	1.0000
sum	5.0760	1.2453

Table 4.4.1.2-17: Normalized matrix for sub criteria under "Customer service"

Main Criteria: Customer Service	Shipping Line's establishment in industry	Status of relationship with Terminal	Average
Shipping Line's establishment in industry	0.1970	0.1970	0.1970
Status of relationship with Terminal	0.8030	0.8030	0.8030

Table 4.4.1.2-18: Relative Weights for sub criteria under main criteria - Customer service

Main Criteria: Customer Service	Average	Rank
Shipping Line's establishment in industry	0.1970	2
Status of relationship with Terminal	0.8030	1

Status of relationship with terminal considered as most important sub criteria.

Main Criteria: Liner Connectivity

Table 4.4.1.2-19: Pairwise comparison matrix for sub criteria under "Liner Connectivity"

Main Criteria: Liner Connectivity	Connectivity from Main/feeder vessels	Connectivity of Inter Terminal Trucking & Export containers
Connectivity from Main/feeder vessels	1.0000	2.0345
Connectivity of Inter Terminal Trucking & Export containers	0.4915	1.0000
sum	1.4915	3.0345

Table 4.4.1.2-20: Normalized matrix for sub criteria under "Liner Connectivity"

Main Criteria: Liner Connectivity	Connectivity from Main/feeder vessels	Connectivity of Inter Terminal Trucking & Export containers	Average
Connectivity from Main/feeder vessels	0.6705	0.6705	0.6705
Connectivity of Inter Terminal Trucking & Export containers	0.3295	0.3295	0.3295

Table 4.4.1.2-21: Relative Weights for sub criteria under main criteria – Liner Connectivity

Main Criteria: Liner Connectivity	Average	Rank
Connectivity from Main/feeder vessels	0.6705	1
Connectivity of Inter Terminal Trucking & Export containers	0.3295	2

Connectivity from Main /feeder lines considered as most important sub criteria.

Main Criteria: Investment in Terminal

Table 4.4.1.2-22: Pairwise comparison matrix for sub criteria under "Investment in Terminal"

Main Criteria: Investment in Terminal	% of shares hold by Shipping Line	Impact of Global Terminal operator
% of shares hold by Shipping Line	1.0000	2.0189
Impact of Global Terminal operator	0.4953	1.0000
sum	1.4953	3.0189

Table 4.4.1.2-23: Normalized matrix for sub criteria under "Investment in Terminal"

Main Criteria: Investment in Terminal	% of shares hold by Shipping Line	Impact of Global Terminal operator	Average
% of shares hold by Shipping Line	0.6688	0.6688	0.6688
Impact of Global Terminal operator	0.3312	0.3312	0.3312

Table 4.4.1.2-24: Relative Weights for sub criteria under main criteria – Investment in Terminal

Main Criteria: Investment in Terminal	Average	Rank
% of shares hold by Shipping Line	0.6688	1
Impact of Global Terminal operator	0.3312	2

4.4.1.3. Summery and Analyzing of the result – Terminal operators' perspective in berth allocation

Table 4.4.1.3-1: Summery and Analyzing of the result – Terminal operators' perspective

Main Criteria	Weightage	Sub Criteria	Weightage
Berthing Pro-Forma	0.2651	Window Arrival	0.7500
		Estimated time of readiness	0.2500
Service Agreements & policies	0.0846	Terminal service Agreements (TSA)	0.6457
		Berthing policy of Terminal	0.3543
Customer service	0.0841	Shipping Line's establishment in industry	0.1970
		Status of relationship with Terminal	0.8030
Commercial aspects	0.1991	Vessel Size (Total containers to be handle)	0.2320
		Domestic container volume	0.1418
		Market share growth rate	0.0630
		Contribution for the revenue of terminal	0.5631
Punctuality of Service	0.0608	Maintaining time schedules	0.2637
		Tidal variations & vessel particulars	0.6350
		Geographical Presence & routes operate	0.1013
Liner Connectivity	0.0747	Connectivity from Main/feeder vessels	0.6705
		Connectivity of Inter Terminal Trucking & Export containers	0.3295
Response to the Special Requirements	0.0310	Emergency requirements	0.1257
		Estimated time of readiness	0.5671
		Readiness of Pre Arrival declaration	0.3072
Investment in Terminal	0.1966	% of shares hold by Shipping Line	0.6688
		Impact of Global Terminal operator	0.3312

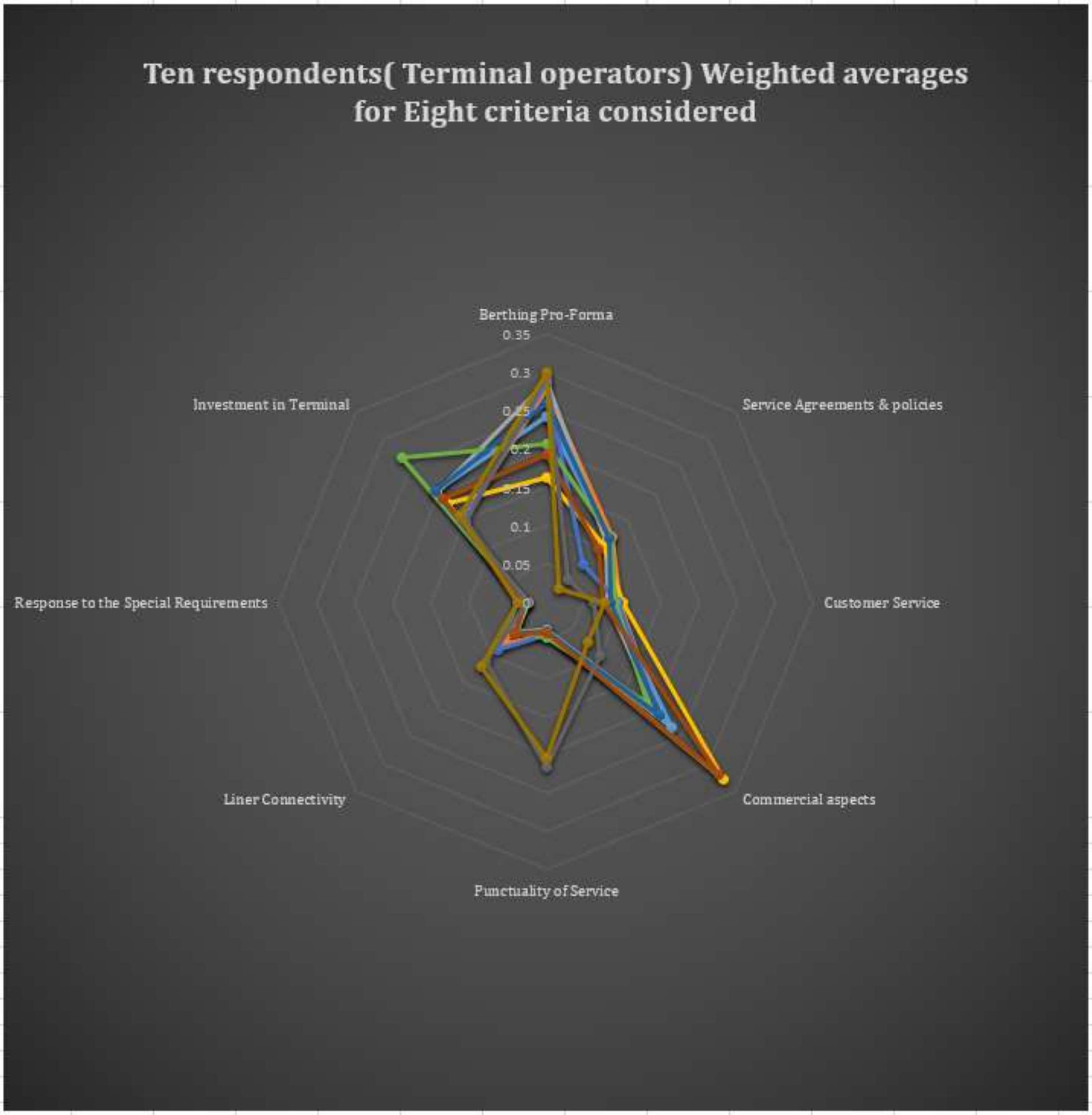


Figure 4-7: Illustration of Terminal Operators' average weights for eight criteria considered in Berth allocation

4.4.1.4. Interpretation of outcome of the Analysis – Terminal Operators' Perspective

From final outcome it's revealed that Transshipment container terminal operators consider "Berthing Pro-forma (0.2651) as a most important criterion" use in berth planning. As indicated terminal operators allocate separate time windows for each and every shipping services operate by different shipping lines which are calling to that terminal according to their requirements and also considering the availability of berths in terminal. On the other hand, it's a right to having a berthing space for a particular vessel calling within a given window time frame. Under this focusing on two sub criteria and from those within window arrival (0.75) consider as most important one than Estimated time of arrival (0.25) given by shipping line prior to seven or three days of the arrival of vessel. The reason is Estimated time of arrival and Actual time of readiness can be within window frame or out of the given window frame.

Commercial aspects (0.1991) ranked as a second most important one following the Berthing Pro-forma. Since terminal operators consider as a service provider in Supply chain and high capital-intensive industry always trying to maximize their revenue by providing various services to the vessels call. Higher share of revenue is generating from stevedoring activities i.e handling of containers. In this case terminal mainly focusing on the shipping lines who generate more revenue to them by handling more container volumes. Not only that when they prioritize vessels in berthing arrangements they are focusing on the container volume both transshipments and exports which are declared to handle at terminal as well. From the sub criteria "contribution for revenue of the terminal" (0.5631) taken in to consider as most important one. Vessel size consider as second most important one and respectively domestic container volume (0.1418) declared to handle and market share growth rate (0.0630) of particular service ranked as third and fourth positions.

In berthing arrangements as per the study results "Shipping Line's investment in terminal" (0.1966) identified as third most important criteria. Here some shipping lines like Maersk, COSCO well known as major container terminal operators in world. On the other was many shipping lines hold some percentage of shares in terminals around the world. Considering that fact, terminal operators should consider this as most important criteria following two criteria above mentioned when arranging berths. Since when shipping line represent as a global terminal operator (0.3312) they usually build their own terminals, sub criteria named as “Number of shares hold by particular shipping line “(0.6668) consider as most important one.

Service agreements and policies (0.0846) consider as a fourth most important criterion. Under this Authority of terminal and particular Shipping line/ Alliance focusing on many criteria like container volume to be handle at terminal, stevedoring and other charges/ rebates etc. Here two sub criteria considered and “Terminal Service Agreements” (0.6457) consider as most important one than “Berthing policy of Terminal” (0.3543).

“Customer service” (0.0841) have ranked as a fifth most important criterion and under these two sub criteria have considered. From those the status of the relationship between terminal and shipping line (0.8031) considered as more important than “shipping line’s establishment within industry” (0.1970).

“Liner connectivity” (0.0747) have identified as sixth most important one from the terminal perspective and under these two sub criteria considered for the analysis. Connectivity from main and feeder vessels (0.6705) have identified as most important one than connectivity of inter terminal trucking and domestic containers (0.3295).

Seventh most important criteria have identified as “Punctuality of service” (0.0608). Under these three sub criteria have analyzed and Tidal variations vessel particulars (0.6350) identified as most important sub criteria while maintaining time schedules and geographical presence and route operates have ranked as second and third while having weights as 0.2637 and 0.1013).

“Response to the special requirements” (0.0310) has identified as least important criteria under this scenario. Under these three sub criteria considered and Estimated time of readiness of vessel considered as most important while other two criteria named readiness of pre-arrival declaration ((0.3070) and emergency requirements (0.1257) ranked in second and third.

4.4.2. Analysis of the Main Container Shipping Lines’ perspective

4.4.2.1. Analysis of the Main criteria consider by Container Shipping Lines when requesting berths for their vessels in Transshipment Container terminals

Under this also pairwise comparison matrix has developed using questionnaire data collected from ten respondents i.e ten major container shipping lines. Here shipping lines’ goal is to request for berths in container terminal they behave like one and since the group becomes a new individual and behaves like one, the reciprocity requirement for the judgments must be satisfied and the geometric mean rather than an arithmetic mean must be used. When individuals are each acting in his or her own right, with different value systems, we are concerned about each individual's resulting alternative priorities. An aggregation of each individual's resulting priorities can be computed using either a geometric or arithmetic mean (Adamcsek, 2008).

Table 4.4.2.1-1: Pair wise comparison matrix for aggregated responds of major Shipping lines (M2)

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Relationship & Market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal
Berthing Pro-Forma	1.0000	5.4355	4.2154	4.0760	2.9542	3.6801	6.1185	3.6801
Service Agreements & policies	0.1840	1.0000	0.2860	0.3167	0.2035	0.2860	2.4082	0.3010
Relationship & Market power	0.2372	3.4968	1.0000	0.2627	0.2627	0.3167	3.3227	0.3010
Commercial aspects	0.2453	3.1572	3.8060	1.0000	0.2717	0.3167	3.3227	0.2142
Punctuality of Service	0.3385	4.9136	3.8060	3.6801	1.0000	3.3227	5.3481	3.4968
Liner Connectivity	0.2717	3.4968	3.1572	3.1572	0.3010	1.0000	3.6165	0.3167
Special Requirements	0.1634	0.4152	0.3010	0.3010	0.1870	0.2765	1.0000	0.2089
Investment in Terminal	0.2717	3.3227	3.3227	4.6689	0.2860	3.1572	4.7877	1.0000
sum	**2.7119**	**25.2379**	**19.8944**	**17.4626**	**5.4661**	**12.3560**	**29.9244**	**9.5187**

Table 4.4.2.1-2: Normalized matrix for aggregated responds of major Shipping lines

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Relationship & Market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal	Average
Berthing Pro-Forma	0.3687	0.2154	0.2119	0.2334	0.5405	0.2978	0.2045	0.3866	0.3073
Service Agreements & policies	0.0678	0.0396	0.0144	0.0181	0.0372	0.0231	0.0805	0.0316	0.0391
Relationship & Market power	0.0875	0.1386	0.0503	0.0150	0.0481	0.0231	0.1110	0.0316	0.0632
Commercial aspects	0.0905	0.1251	0.1913	0.0573	0.0497	0.0256	0.1110	0.0225	0.0841
Punctuality of Service	0.1248	0.1947	0.1913	0.2107	0.1829	0.2689	0.1787	0.3674	0.2149
Liner Connectivity	0.1002	0.1386	0.1587	0.1808	0.0551	0.0809	0.1209	0.0333	0.1085
Special Requirements	0.0603	0.0165	0.0151	0.0172	0.0342	0.0224	0.0334	0.0219	0.0276
Investment in Terminal	0.1002	0.1317	0.1670	0.2674	0.0523	0.2555	0.1600	0.1051	0.1549

Table 4.4.2.1-3: Relative Weights for criteria consider by Major Container Shipping Lines when requesting for berths in transshipment container terminals

Berth Requesting Criteria	Average	Rank
Berthing Pro-Forma	0.3073	1
Service Agreements & policies	0.0391	7
Relationship & Market power	0.0632	6
Commercial aspects	0.0841	5
Punctuality of Service	0.2149	2
Liner Connectivity	0.1085	4
Special Requirements	0.0276	8
Investment in Terminal	0.1549	3

Berthing Pro-Forma considered as most important criteria and Punctuality of service considered as second most important one.

Consistency Analysis

This step is carryout in order to measure the consistency of response in pairwise comparison.

ƛ max	9.0632	
CI, when No of comparisons, n is equal to 8	CI= (ƛ max-1)/(n-1)	= (9.0632-1)/(8-1) = 0.15188
CR	CR= CI/RI	RI=1.41 (For n=8)
CR	**0.1077**	

CR value is acceptable since value is lying between 0.1 – 0.15

4.4.2.2. Analysis of the Sub criteria under each main criterion consider by Container Shipping lines when requesting for berths in Transshipment container terminals

Main Criteria: Punctuality of Service

Table 4.4.2.2-1: Pairwise comparison matrix for sub criteria under "Punctuality of Service"

Punctuality of service	**Maintaining time schedules**	**Tidal variations & vessel particulars**	**Geographical Presence & routes operate**
Maintaining time schedules	1.0000	4.3227	4.4364
Tidal variations & vessel particulars	0.2313	1.0000	0.2717
Geographical Presence & routes operate	0.2254	3.6801	1.0000
Sum	**1.4567**	**9.0028**	**5.7081**

Table 4.4.2.2-2: Normalized matrix for sub criteria under "Punctuality of Service"

Punctuality of service	Maintaining time schedules	Tidal variations & vessel particulars	Geographical Presence & routes operate
Maintaining time schedules	0.6865	0.4802	0.7772
Tidal variations & vessel particulars	0.1588	0.1111	0.0476
Geographical Presence & routes operate	0.1547	0.4088	0.1752

Table 4.4.2.2-3: Relative Weights for sub criteria under main criteria – Punctuality of Service

	Average	Rank
Maintaining time schedules	0.6479	1
Tidal variations & vessel particulars	0.1058	3
Geographical Presence & routes operate	0.2462	2

Maintaining of time schedules considered as most important criteria.

Main Criteria: Special Requirements

Table 4.4.2.2-4: Pairwise comparison matric for sub criteria under "Special Requirements"

	Emergency requirements	Estimated time of readiness	Readiness of Pre Arrival declaration
Emergency requirements	1.0000	4.3597	3.3227
Estimated time of readiness	0.2294	1.0000	2.9770
Readiness of Pre Arrival declaration	0.3010	0.3359	1.0000
Sum	1.5303	5.6956	7.2997

Table 4.4.2.2-5: Normalized matrix for sub criteria under "Special Requirements"

	Emergency requirements	Estimated time of readiness	Readiness of Pre Arrival declaration
Emergency requirements	0.6535	0.7654	0.4552
Estimated time of readiness	0.1499	0.1756	0.4078
Readiness of Pre Arrival declaration	0.1967	0.0590	0.1370

Table 4.4.2.2-6: Relative Weights for sub criteria under main criteria – Special Requirements

	Average	Rank
Emergency requirements	0.6247	1
Estimated time of readiness	0.2444	2
Readiness of Pre Arrival declaration	0.1309	3

Emergency requirements considered as most important sub criteria.

Main Criteria: Berthing Pro-Forma

Table 4.4.2.2-7: Pairwise comparison matrix for sub criteria under "Pro-Forma"

Berthing Pro- Forma	Window Arrival	ETA
Window Arrival	1.0000	0.8448
ETA	1.1837	1.0000
Sum	2.1837	1.8448

Table 4.4.2.2-8: Normalized matrix for sub criteria under "Berthing Pro-Forma"

Berthing Pro- Forma	Window Arrival	ETA
Window Arrival	0.4579	0.4579
ETA	0.5421	0.5421

Table 4.4.2.2-9: Relative Weights for sub criteria under main criteria – Berthing Pro-Forma

	Average	Rank
Window Arrival	0.45793966	2
ETA	0.54206034	1

Estimated time of readiness considered as most important sub criteria.

Main Criteria: Service Agreements and Policies

Table 4.4.2.2-10: Pairwise comparison matrix for sub criteria under "Service agreements and policies"

Service agreements and policies	Terminal service Agreements (TSA)	Berthing policy of Terminal
Terminal service Agreements (TSA)	1.0000	4.3597
Berthing policy of Terminal	0.2294	1.0000
Sum	1.2294	5.3597

Table 4.4.2.2-11: Normalized matrix for sub criteria under "Service Agreements and Policies"

Service agreements and policies	Terminal service Agreements (TSA)	Berthing policy of Terminal
Terminal service Agreements (TSA)	0.8134	0.8134
Berthing policy of Terminal	0.1866	0.1866

Table 4.4.2.2-12: Relative Weights for sub criteria under main criteria – Service Agreements and Policies

Service agreements and policies	Average	Rank
Terminal service Agreements (TSA)	0.8134	1
Berthing policy of Terminal	0.1866	2

TSA agreement considered as most important sub criteria.

Main Criteria: Relationship and Market Power

Table 4.4.2.2-13: Pairwise comparison matrix for sub criteria under "Relationship and market power"

Relationship and Market power	Bargaining power of shipping line/Alliance	Status of relationship with Terminal
Bargaining power of shipping line/Alliance	1.0000	0.4670
Status of relationship with Terminal	2.1411	1.0000
Sum	3.1411	1.4670

Table 4.4.2.2-14: Normalized matrix for sub criteria under "Relationship and Market power"

Relationship and Market power	Bargaining power of shipping line/Alliance	Status of relationship with Terminal
Bargaining power of shipping line/Alliance	0.3184	0.3184
Status of relationship with Terminal	0.6816	0.6816

Table 4.4.2.2-15: Relative Weights for sub criteria under main criteria – Relationship and Market power

Relationship and Market power	Average	Rank
Bargaining power of shipping line/Alliance	0.3184	2
Status of relationship with Terminal	0.6816	1

Status of relationship with terminal considered as most important sub criteria.

Main Criteria: Commercial aspects

Table 4.4.2.2-16: Pairwise comparison matrix for sub criteria under "Commercial aspects"

Commericial Aspects	Contribution for the revenue of terminal	Total Volume carrying by vessel(Domestic +Transhipment)
Contribution for the revenue of terminal	1.0000	2.2533
Total Volume carrying by vessel(Domestic +Transhipment)	0.4438	1.0000
Sum	1.4438	3.2533

Table 4.4.2.2-17: Normalized matrix for sub criteria under "Commercial aspects"

Commericial Aspects	Contribution for the revenue of terminal	Total Volume carrying by vessel(Domestic +Transhipment)
Contribution for the revenue of terminal	0.6926	0.6926
Total Volume carrying by vessel(Domestic +Transhipment)	0.3074	0.3074

Table 4.4.2.2-18: Relative Weights for sub criteria under main criteria – Commercial aspects

Commericial Aspects	Average	Rank
Contribution for the revenue of terminal	0.6926	1
Total Volume carrying by vessel(Domestic +Transhipment)	0.3074	2

Contribution for the revenue of terminal considered as most important sub criteria.

Main Criteria: Liner Connectivity

Table 4.4.2.2-19: Pairwise comparison matrix for sub criteria under "Liner Connectivity"

Liner Connectivity	Connectivity from Main/feeder vessels	Connectivity of Inter Terminal Trucking & Export containers
Connectivity from Main/feeder vessels	1.0000	1.3904
Connectivity of Inter Terminal Trucking & Export containers	0.7192	1.0000
Sum	1.7192	2.3904

Table 4.4.2.2-20: Normalized matrix for sub criteria under "Liner Connectivity"

Liner Connectivity	Connectivity from Main/feeder vessels	Connectivity of Inter Terminal Trucking & Export containers
Connectivity from Main/feeder vessels	0.5817	0.5817
Connectivity of Inter Terminal Trucking & Export containers	0.4183	0.4183

Table 4.4.2.2-21: Relative Weights for sub criteria under main criteria – Liner Connectivity

Liner Connectivity	Average	Rank
Connectivity from Main/feeder vessels	0.5817	1
Connectivity of Inter Terminal Trucking & Export containers	0.4183	2

Connection from main and feeder line vessels considered as most important sub criteria.

Main Criteria: Investment in Terminal

Table 4.4.2.2-22: Pairwise comparison matrix for sub criteria under "Investment in Terminal"

Investment in Terminal	Return on Investment	Presence as Global Terminal operator
Return on Investment	1.0000	4.5144
Presence as Global Terminal operator	0.2215	1.0000
Sum	1.2215	5.5144

Table 4.4.2.2-23: Normalized matrix for sub criteria under "Investment in Terminal"

Investment in Terminal	Return on Investment	Presence as Global Terminal operator
Return on Investment	0.8187	0.8187
Presence as Global Terminal operator	0.1813	0.1813

Table 4.4.2.2-24: Relative Weights for sub criteria under main criteria – Investment in Terminal

	Average	Rank
Return on Investment	0.818656682	1
Presence as Global Terminal operator	0.181343318	2

Return on investment considered as most important sub criteria.

4.4.2.3. Summery and Analyzing of the results- Shipping Lines' perspective in berth allocation

Table 4.4.2.3-1: Summery and Analyzing of the results- Shipping Lines' perspective

Main criteria	Weightage	Subcriteria	Weightage
Berthing Pro-Forma	0.3073	Within Window Arrival	0.4579
		Estimated Time of Arrival	0.5421
Service Agreements & policies	0.0391	Terminal Service agreements (TSA) between terminal & shipping lines (In case of alliance service, TSA with alliance partners)	0.8134
		Berthing policy of an organization / Terminal	0.1866
Relationship & Market power	0.0632	Bargaining power of shipping line/Alliance	0.3184
		Status of the relationship with terminal	0.6816
Commercial aspects	0.0841	Contribution for the revenue of terminal (Percentage of the container volume in TEUs handle in terminal)	0.6926
		Container volume (including domestic) carrying by the particular vessel (i.e berth requested)	0.3074
Punctuality of Service	0.2149	Maintain time schedules (Windows of leading ports and Terminals,Suez, Panama)	0.6479
		Tidal Variations and vessel particulars	0.1058
		Geographical presence & routes operate (East bound -West bound , North bound-South bound)	0.2462
Liner Connectivity	0.1085	Connectivity of the Feeder Network & Main line vessels	0.5817
		Connectivity of Inter Terminal trucking (ITT) & Export containers	0.4183
Special Requirements	0.0276	Emergency requirements such as health problem of crew member, fire on board/ bunkering, on board / hull repairing /fresh water etc	0.6247
		Estimated time of Readiness of the vessel	0.2444
		Readiness of Pre arrival declaration (ISPS, Dangerous cargo, Port clearance on payments & other relevant documents)	0.1309
Investment in Terminal	0.1549	Return on Investment consideration	0.8187
		Presence as Global Terminal operator	0.1813

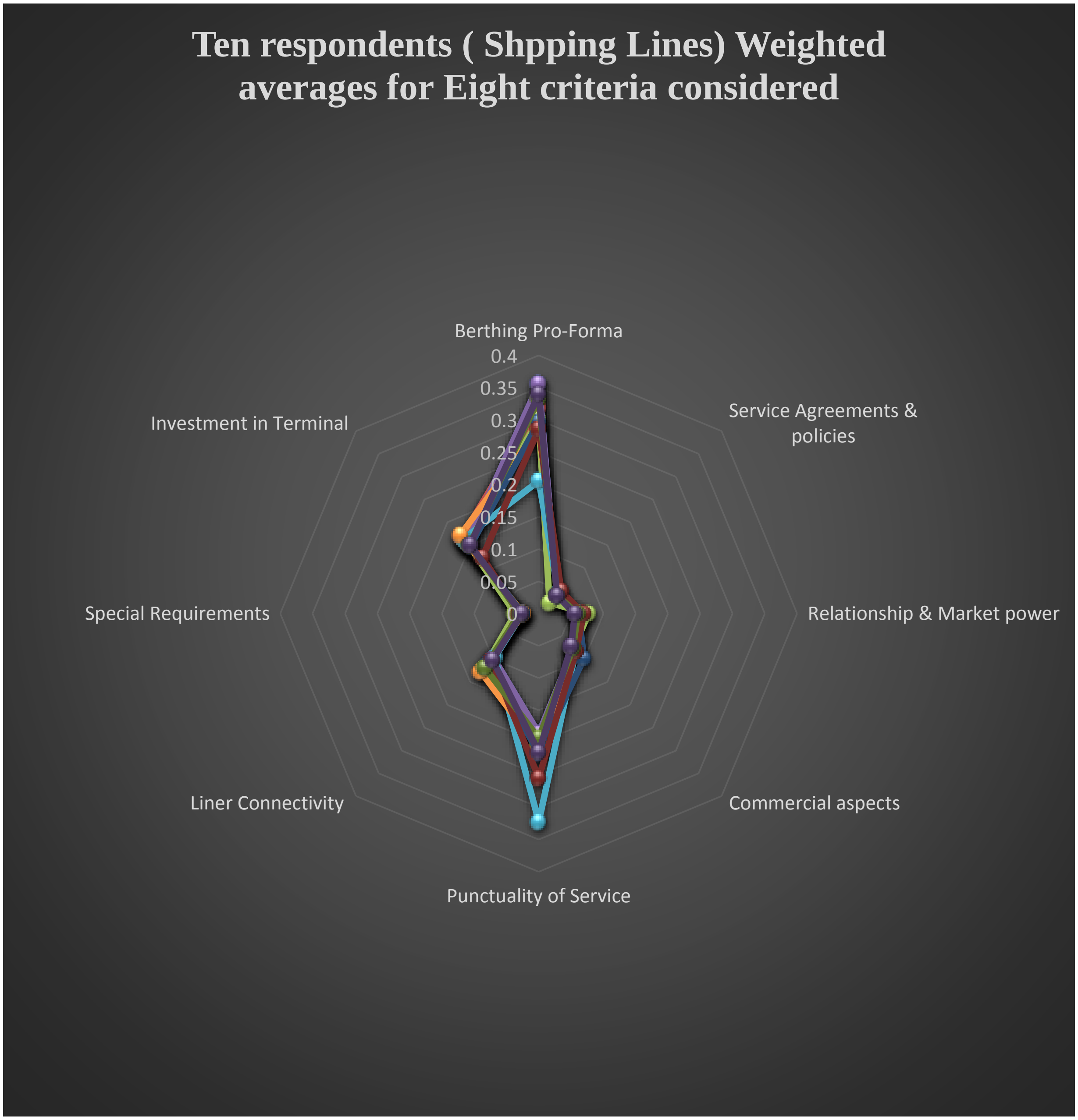


Figure 4-8: Illustration of Shipping Lines' average weights for eight criteria considered in Berth allocation

4.4.2.4. Interpretation of outcome of the *Analysis* – Terminal Operators' Perspective

From final outcome it's revealed that Shipping Line operators consider "Berthing Pro-forma (0.3073) as a most important criterion" they have considered when requesting berths. As indicated terminal operators allocate separate time windows for each and every shipping services operate by different shipping lines which are calling to that terminal according to their requirements and also considering the availability of berths in terminal. On the other hand, it's a right to having a berthing space for a particular vessel calling within a given window time frame. Under this focusing on two sub criteria and from those within window arrival (0.4579) consider as most important one than Estimated time of arrival (0.5421) given by shipping line prior to seven or three days of the arrival of vessel. The reason why shipping lines more focusing on ETA is that they may delay from the window and then they strive to get on arrival berth at terminal irrespective to the window arrangements to maintain schedule reliability.

Punctuality of service (0.2149) ranked as a second most important one following the Berthing Pro-forma. Under these three sub criteria have analyzed and maintaining time schedules (0.6479) have ranked as most important while other two named geographical presence and route operates (0.2462) and tidal variations and vessel particulars (0.1058) ranked as second and third positions.

Investment made in terminal (0.1549) considered as third most important criteria. Two sub criteria have discussed under this and "return on investment" (0.8187) considered as most important one than "presence as global terminal operator" (0.1813).

"Liner connectivity" (0.1085) have identified as fourth most important one from the Shipping Lines' perspective and under these two sub criteria considered for the analysis. Connectivity from main and feeder vessels (0.5817) have identified as most important one than connectivity of inter terminal trucking and domestic containers (0.4183).

Commercial aspects ranked as fifth most important (0.0841). Under this under these two sub criteria have considered and contribution for revenue of terminal (0.6926) considered to be more important than container volume handle by particular vessel (0.3047).

Relationship and market power (0.0632) ranked as sixth most important and again two sub criteria have analyzed. The relationship with terminal (0.6816) considered more important than bargaining power (0.3184).

Service agreements and policies (0.0391) placed in seventh position and two sub criteria have considered under this. Under this “terminal service agreement between terminal and Shipping line/Alliance” (0.8134) considered more important than “Berthing policy of terminal” (0.1866).

“Special requirements” (0.0276) has identified as least important criteria under this scenario. Under these three sub criteria considered and “emergency requirements” (0.6247) ranked at top. Estimated time of readiness (i.e Vessel readiness) (0.2444) and “readiness of pre- arrival declaration” (0.1309) has ranked in second and third positions.

4.4.3. Combination of the both aspects

Combined matrix has obtained by multiplying pairwise comparison matrix which was generated using Terminal operators’ responses by Pairwise comparison matrix which was generated using shipping lines’ opinions.

Common matrix = M1 * M2

Where,

M1 = Pairwise Comparison Metrix for the aggregated responds of Terminal operators

M2 =Pair wise comparison matric for aggregated responds of major Shipping lines

Table 4.4.2.4-1: Pairwise Comparison matrix – Combined perspective of Terminal operators and Shipping Lines

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Relationship & Market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal
Berthing Pro-Forma	12.4337	45.9626	46.2454	15.2859	57.2192	48.4049	104.8860	17.2499
Service Agreements & policies	1.5966	5.2848	5.2966	1.9515	6.7413	5.5737	12.1887	2.0205
Relationship & Market power	2.5375	8.6610	9.9687	3.1109	14.0596	11.3071	24.3290	3.2207
Commercial aspects	3.4361	12.6919	14.6289	4.5159	20.8716	17.9101	38.9591	5.0114
Punctuality of Service	10.4988	38.5834	39.1226	12.1973	47.4907	41.3494	87.0631	14.4152
Liner Connectivity	4.8094	21.5445	22.8549	7.0804	28.8017	23.1833	50.8047	8.3406
Special Requirements	1.0422	3.7821	3.7050	1.3724	4.6984	3.8548	8.3516	1.3949
Investment in Terminal	7.2018	31.0759	31.4160	10.2747	39.4810	31.3156	69.6704	12.0799
sum	43.5561	167.5863	173.2380	55.7891	219.3634	182.8988	396.2525	63.7331

Table 4.4.2.4-2: Normalized matrix – Combined perspective of Terminal operators and Shipping Lines

Berth Requesting Criteria	Berthing Pro-Forma	Service Agreements & policies	Relationship & Market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal	Average
Berthing Pro-Forma	0.2855	0.2743	0.2669	0.2740	0.2608	0.2647	0.2647	0.2707	0.2702
Service Agreements & policies	0.0367	0.0315	0.0306	0.0350	0.0307	0.0305	0.0308	0.0317	0.0322
Relationship & Market power	0.0583	0.0517	0.0575	0.0558	0.0641	0.0305	0.0614	0.0505	0.0537
Commercial aspects	0.0789	0.0757	0.0844	0.0809	0.0951	0.0979	0.0983	0.0786	0.0863
Punctuality of Service	0.2410	0.2302	0.2258	0.2186	0.2165	0.2261	0.2197	0.2262	0.2255
Liner Connectivity	0.1104	0.1286	0.1319	0.1269	0.1313	0.1268	0.1282	0.1309	0.1269
Special Requirements	0.0239	0.0226	0.0214	0.0246	0.0214	0.0211	0.0211	0.0219	0.0222
Investment in Terminal	0.1653	0.1854	0.1813	0.1842	0.1800	0.1712	0.1758	0.1895	0.1791

Table 4.4.3-3 Relative Weights for Combined aspects

Berth Requesting Criteria	Average	Rank
Berthing Pro-Forma	0.2702	1
Service Agreements & policies	0.0322	7
Relationship & Market power	0.0537	6
Commercial aspects	0.0863	5
Punctuality of Service	0.2255	2
Liner Connectivity	0.1269	4
Special Requirements	0.0222	8
Investment in Terminal	0.1791	3

4.4.3.1. Interpretation of analysis data generated from common modal

Derived result from combined matrix can show as in table no4.4.3-4. As in both aspects here also "Berthing Pro-Forma" ranked as criteria which use in priority in berthing arrangements. Container terminal operators use this as a tool which maximize their berth occupancy and to identify how their customers positions in their terminal layout with time factor. Shipping lines also consider as their right which use to confirm the berth availably in maintaining their sailing schedules.

Punctuality of service ranked as second most important criteria in berth allocation. Especially Shipping lines consider punctuality as most important factor and from other aspect transshipment terminal operators also highly focusing on the service where particular vessels deployed.

Investment in terminals ranked as third most important criteria as both terminal operators and Shipping lines expecting mutual benefits from that. In fourth placed Liner connectivity since it denotes about the cargo volume which benefits for both parties. Commercial aspect considered as fifth important criteria while relationship and market power considered to be sixth important criteria.

Service agreements and policies ranked in seventh position and special requirements ranked in eighth position since it is criteria which use only in special occasions.

4.5. Regression & Correlation Analysis for Deciding on the Efficiency of Berth Allocation

As per the APH model findings; Berth Allocation is influenced by several critical parameters which varies from high importance to low importance and the regression analysis method has been carried out to define the significance of each independent variable to dependent variable of Berth Allocation. Thus; based on the interpreted data which are gathered from the questionnaire; circulated among 10 container terminals, Regression question has been derived as follows.

4.5.1. Regression & Correlation Analysis for Deciding on the Efficiency of Berth Allocation

Major determinant for deciding on Berth Allocation (BA) (only 05 parameters have been considered based on the ranking of APH model)

1. Berthing Pro-forma (BP)
2. Commercial Aspects (CA)
3. Punctuality of Service (PS)
4. Liner Connectivity (LC)
5. Investment in Terminal (IT)

Hence Regression equation,

Berthing Allocation (BA) =f (BP, CA, PS, LC, IT)

4.5.2. Regression Analysis

Since Berth Allocation is determined by the variables of BP, CA, PS, LC, IT; multiple regression method has been used as follows to define its relationship.

Table 4.5-1: Regression Output

Variable	Coefficient	t value	P value
Constant	-0.033	-0.042	0.966
Berthing Pro-forma (BP)	0.427**	3.339	0.003
Commercial Aspects (CA)	0.051**	0.493	0.627
Punctuality of Service (PS)	0.413**	2.608	0.015
Liner Connectivity (LC)	0.156**	1.325	0.198
Investment in Terminal (IT)	0.169**	1.291	0.209
R2	61.6%		
F Statistics			7.713
(P value)			0.000

**- Significant at 1% Level

Multiple Regression Equation

$$\mathbf{Y = 0.427BP + 0.051CA + 0.413\ PC + 0.156LC + 0.169IT - 0.033}$$

4.5.3. Measuring the significance of the Model

Coefficient of Determination (R Square) = 0.616

Above figure prove that; even though there are several other variables which can be impact over the dependent variable of Berth Allocation; the dependent variable is explained 61.6% by the selected independent variables of BP, CA, PS, LC & IT. Based on the ranking of AHP analysis in common approach only considered 05 variables out of 09 variables which explain rest of 38% of independent variable.

4.5.4. Descriptive Statistics

Table 4.5-2: Descriptive data Analysis of the Study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Berth_Allocation	30	3.70	5.00	4.3500	.34416
Berthing_Proforma	30	3.00	4.70	3.9400	.38650
Commercial_Aspects	30	2.00	3.70	2.5867	.50701
Punctuality_of_Service	30	3.70	4.70	4.0033	.28099
Liner_Connectivity	30	2.00	4.00	2.8367	.44449
Investment_in_Terminal	30	2.00	3.30	2.7867	.38032
Valid N (listwise)	30				

For the regrssion analysis, selected the sample of 30 terminal operations managers (Including the operations managerial level of ten terminal used in AHP analysis process). For that sample descriptive data such as medium, mean are explined by above table.

4.5.5. Correlation Analysis

As per defined dependent and independent variables; the signs of the coefficients which determine the relationship to the dependent variable have been derived by using following SPSS output.

Table 4.5-3: Correlation Output

		Berthing Allocation (BA)	Berthing Pro-forma (BP)	Commercial Aspects (CA)	Punctuality of Service (PS)	Liner Connectivity (LC)	Investment in Terminal (IT)
Berthing Allocation (BA)	Pearson Coefficient	1					
	Sig (2 tailed)						
Berthing Pro-forma (BP)	Pearson Coefficient	0.612	1				
	Sig (2 tailed)	0.000					
Commercial Aspects (CA)	Pearson Coefficient	0.379	0.274	1			
	Sig (2 tailed)	0.039	0.143				
Punctuality of Service (PS)	Pearson Coefficient	0.419	0.084	0.206	1		
	Sig (2 tailed)	0.021	0.657	0.275			
Liner Connectivity (LC)	Pearson Coefficient	0.366	0.075	0.463	0.120	1	
	Sig (2 tailed)	0.047	0.692	0.010	0.526		
Investment in Terminal (IT)	Pearson Coefficient	0.424	0.363	0.053	0.007	0.284	
	Sig (2 tailed)	0.019	0.049	0.782	0.971	0.128	1

As illustrates above, Pearson correlation coefficient of all five independent variables of Berthing Pro-forma (BP), Commercial Aspects (CA), Punctuality of Service (PS), Liner Connectivity (LC) and Investment in Terminal (IT) have encountered with different values of 0.612, 0.379, 0.419, 0.366 and 0.424 respectively. Since all these values ascertained with positive figures; it proves that all these five independent variables have positive correlation with the dependent variable of Berth Allocation (BA). Thus, when these independent variables have increased; the Berth Allocation will be increased accordingly.

4.5.6. Determining the Coefficient of parameters

When referring the p value of ANOVA table; P-value = 0.000 < α. Thus, selected independent variables of BP, CA, PS, LC and IT are more or less impact over the dependent variable of Berth Allocation and each independent variable's optimum level of relationships with the dependent variable have been defined below.

4.5.7. Relationship between Berth Allocation and Berthing Pro-Forma

Berthing Performa have been derived with regards to the Berth allocation based on three questions in questionnaires and average values of each questions were taken in to consideration. The Pearson Correlation Coefficient and the P value which are derived using the SPSS Software have been utilized to test the hypothesis.

$H0_1$ There is no relationship between Berth Allocation and Berthing Pro-Forma

Ha_1 There is a relationship between Berth Allocation and Berthing Pro-Forma

As per the analysis, Pearson Correlation of between Berth Allocation and Berthing Pro-Forma is 0.612

Therefore, ρ value = +0.612

Probability value P = 0.000

Probability value P < 0.05 which emphasize that the significance level of alternate hypothesis is achieved and hence, H_1 is accepted to be true. Therefore, it is accepted that there is a relationship between Berth Allocation and Berthing Pro-Forma**.**

Since ρ value falls between + 0.6 and + 1.0; it is evident that there is a **Strong relationship** between Berth Allocation and Berthing Pro-Forma

4.5.8. Relationship between Berth Allocation and Commercial Aspect

Commercial Aspect is analyzed with three criteria related to Berth Allocation and the relationship between these two parameters is derived via Pearson Coefficient analysis using SPSS software.

Hypothesis defined for the above two variables are as follows:

$H0_2$ There is no relationship between Berth Allocation and Commercial Aspect

Ha_2 There is a relationship between Berth Allocation and Commercial Aspect

Pearson correlation of Berth Allocation and Commercial Aspect is = 0.379

Therefore, the ρ value = + 0.38

Probability P value = 0.039

Probability value $P < 0.05$ which emphasize that the significance level of alternate hypothesis is achieved and hence, H_1 is accepted to be true. Therefore, it is accepted that there is a relationship between Berth Allocation and Commercial Aspect

As the ρ value located in between +0.3 to +0.6, but it is more towards +0.3; it can be stated that there is a **weak relationship between Berth Allocation and Commercial Aspect**

4.5.9. Relationship between Punctuality of Service and Berth Allocation

Related to Punctuality of Services, three criteria were measured with three questions and the analysis is as follows:

$H0_3$ There is no relationship between Punctuality of Services and Berth Allocation

Ha_3 There is a relationship between Punctuality of Services and Berth Allocation

Pearson correlation of Berth Allocation and Punctuality of Service is = 0.419

Therefore, the ρ value (ρ) = + 0.42

Probability P-Value = 0.021

As the ρ value located in between +0.3 and +0.6, the above relationship signifies a **moderate positive relationship** between the two variables.

4.5.10. Relationship between Berth Allocation and Liner connectivity

Since liner connectivity also impact over berth allocation; liner connectivity is analyzed with three criteria related to berth allocation. Thus, the relationship between the dependent variable and the liner connectivity is derived via Pearson Coefficient analysis using SPSS software.

Hypothesis defined for the above two variables are as follows:

$H0_2$ There is no relationship between Berth Allocation and Liner Connectivity

Ha_2 There is a relationship between Berth Allocation and Liner Connectivity

Pearson correlation of Liner Connectivity and Berth Allocation is =0.366

Therefore, the ρ value = + 0.37

Probability P value = 0.047

Probability value $P < 0.05$ which emphasize that the significance level of alternate hypothesis is achieved and hence, H_1 is accepted to be true. Therefore, it is accepted that there is a relationship between Berth Allocation and Liner Connectivity.

As the ρ value located in between +0.3 to +0.6, but it is more towards +0.3; it can be stated that there is a **Weak relationship between** Berth Allocation and Liner Connectivity

4.5.11. Relationship between Punctuality of Service and Berth Allocation

Related to Punctuality of Services, three criteria were measured with three questions and the analysis is as follows:

$H0_3$ There is no relationship between Punctuality of Services and Berth Allocation

Ha_3 There is a relationship between Punctuality of Services and Berth Allocation

Pearson correlation of Berth Allocation and Punctuality of Service is = 0.419

Therefore, the ρ value (ρ) = + 0.42

Probability P-Value = 0.021

As the ρ value located in between +0.3 and +0.6, the above relationship signifies a **moderate positive relationship** between the two variables.

4.5.12. Relationship between Berth Allocation and Investment in Terminal

With the defined questions with regards to the Investment in terminal towards the Berth Allocation; Pearson Coefficient analysis is carried out using SPSS software as follows.

Hypothesis defined for the above two variables are as follows:

$H0_2$ There is no relationship between Berth Allocation and Investment in Terminal

Ha_2 There is a relationship between Berth Allocation and Investment in Terminal

Pearson correlation of Investment in Terminal and Berth Allocation is =0.424

Therefore, the ρ value = + 0.43

Probability P value = 0.019

As the ρ value located in between +0.3 to +0.6, but it is more towards +0.6; it can be stated that there is a **moderate relationship between** Berth Allocation and Investment in Terminal

Probability value $P < 0.05$ which emphasize that the significance level of alternate hypothesis is achieved and hence, H_1 is accepted to be true. Therefore, it is accepted that there is a relationship between Berth Allocation and Investment in Terminal.

4.5.13. Summary of the outcome of relationship status

Berth Allocation & Berthing Performa

- **Stong Relationship**

Berth Allocation & Commercial Aspects

- **Weak Relationship**

Berth Allocation & Puntuality of Services

- **Moderate Relationship**

Berthing Allocation & Liner Connectivity

- **Weak Relationship**

Berthing Allocation & Investment in Terminal

- **Moderate Relationship**

As per the correlation analysis regarding the relationship it was revealed that “berthing pro-forma” has a strong relationship with Berth allocation. Due to that it can make a big impact on berth allocation and terminal operators should focus on this giving higher priority level.

Apart from that “punctuality of service” and “investment in terminal” have moderate relationships with Berth allocation.

Further “commercial aspects” and “Liner connectivity” have week relationships with berth allocation.

4.6. Application of the AHP rankings to the real-world scenario in berth Allocation

Table 4.6-1: Details relevant to berthing for the Liner services A and B

Criteria	**Service -A**	**Service -B**
Berthing Pro-Forma	Pro-Forma window - 2300hrs Sunday-1800hrs Saturday { ***ETA- 2400hrs Friday*** }	Proforma window -2200 hrs Friday - 1800hrs Saturday {***ETA -18 hrs Friday*** }
Service agreements and policies	TSA Customer	TSA Customer
Relationship and market power	New customer in Jaya Container Terminal & Powerful in Asian Region	Oldest & loyal customer in Jaya Container Terminal-Port of Colombo
Comparison with respect to Commercial aspects	4600 containers to be handle 1700 domes	2500 containers to be handle (260 Domestics)
	30% revenue generate from operation/yr,Usually Handle more domestic containers	26% of revenue generate from operation/yr , Handle highest volume of Transhipment containers in terminal
Comparison with respect to punctuality of service	West bound via Suez to Nort America	East Bound to Europe to Shanghai-China
Comparison with respect to Liner connectivity	700 loading containers from other terminal	500 containers from other terminal vessels and 100 export conatiners
Comparison with respect to Special requirements	Bunkering, Crew Change	Hull painting, Bunkering
Comparison with respect to Investment in Terminal	No	No

Here consider two container Shipping services Name A and B, calling to Jaya Container terminal in Port of Colombo. Details of the voyage categorized in to eight criteria considered within this study and summarized in table no 4.5-1. Using Analytical Hierarchy Process technique indicated details can rank and shown as below in table no 4.5-1.

Table 4.6-2: Comparison and ranking of the both liner services A and B

	A								B
	9	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**
Comparison with respect to Berthing Pro-Forma			5						
Comparison with respect to Service agreements and policies					1				
Comparison with respect to Relationship and market power								0.143	
Comparison with respect to Commercial aspects			5						
Comparison with respect to punctuality of service		7							
Comparison with respect to Liner connectivity					1				
Comparison with respect to Special requirements					1				
Comparison with respect to Investment in Terminal					1				

Using the process pairwise comparison matrices and Normalized matrices have developed and indicate below table no 4.5.3.

Table 4.6-3: Pairwise comparison and Normalized matrixes

Pairwaise Comparison matrix		
Pro-Forma	A	B
A	1	5
B	0.2	1
Sum	1.2	6

Normalyzed matrix			
Pro-Forma	A	B	Average
A	0.833333333	0.833333333	0.833333
B	0.166666667	0.166666667	0.166667
Sum	1	1	

Service Agreements	A	B
A	1	1
B	1	1
Sum	2	2

Service Agreements	A	B	Average
A	0.5	0.5	0.5
B	0.5	0.5	0.5
Sum	1	1	

Relationship/Market power	A	B
A	1	0.142857143
B	7	1
Sum	8	1.142857143

Relationship/Market power	A	B	Average
A	0.125	0.125	0.125
B	0.875	0.875	0.875
Sum	1	1	

Commercial aspects	A	B
A	1	5
B	0.2	1
Sum	1.2	6

Commercial aspects	A	B	Average
A	0.833333333	0.833333333	0.833333
B	0.166666667	0.166666667	0.166667
Sum	1	1	

Punctuality of Service	A	B
A	1	7
B	0.142857143	1
Sum	1.142857143	8

Punctuality of Service	A	B	Average
A	0.875	0.875	0.875
B	0.125	0.125	0.125
Sum	1	1	

Liner connectivity	A	B
A	1	1
B	1	1
Sum	2	2

Liner connectivity	A	B	Average
A	0.5	0.5	0.5
B	0.5	0.5	0.5
Sum	1	1	

Special requirements	A	B
A	1	1
B	1	1
Sum	2	2

Special requirements	A	B	Average
A	0.5	0.5	0.5
B	0.5	0.5	0.5
Sum	1	1	

Investment	A	B
A	1	1
B	1	1
Sum	2	2

Investment	A	B	Average
A	0.5	0.5	0.5
B	0.5	0.5	0.5
Sum	1	1	

Following table shows the weights generated for each criterion separately for services named as A and B.

	Berthing Pro-Forma	Service Agreements and policies	Relationship and market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal
Criteria Weights	**0.2702**	**0.0322**	**0.0537**	**0.0863**	**0.2255**	**0.1269**	**0.0222**	**0.1791**
A	0.83333	0.5	0.125	0.83333	0.875	0.5	0.5	0.5
B	0.16667	0.5	0.875	0.16667	0.125	0.5	0.5	0.5

Following table shows that Container shipping service A received higher weight (0.6813) than B (0.3147) and then prioritization should be given to the Service A in berth allocation.

Table 4.6-0-4: Average weights generated for Liner Service A and B

	Berthing Pro-Forma	Service Agreements and policies	Relationship and market power	Commercial aspects	Punctuality of Service	Liner Connectivity	Special Requirements	Investment in Terminal	Sum
Criteria Weights	**0.2702**	**0.0322**	**0.0537**	**0.0863**	**0.2255**	**0.1269**	**0.0222**	**0.1791**	
A	0.22517	0.0161	0.00671	0.07192	0.19731	0.06345	0.0111	0.08955	**0.68131**
B	0.04503	0.0161	0.04699	0.01438	0.02819	0.06345	0.0111	0.08955	**0.31479**

5. Conclusion

5.1. Introduction

Berth allocation in Transshipment container terminals can consider as a most critical and important activity which should be planned in strategic ways. Considering the importance of that fact, this research was focused on the Development of conceptual model for main line container vessel berth allocation in a Transhipment Container Terminal

This chapter is structured to present the summery of research findings which achieve one main and four sub objectives, final wording for the research and recommendations. Further, research limitations were discussed and finally the chapter is concluded with giving future research directions.

5.2. Summary of Research Findings

Research was carried out to achieve the main objective of develop a common model which can use when allocating berth to container vessel which beneficial for both shipping line and container terminal. Main objective was supported by four sub objectives as,

1. Identify and categorize the unique factors consider by container terminal operators when allocating berths for main line container vessels and identify and categorize the unique factors consider by Shipping Lines when requesting berths in container terminal
2. Weight and rank the criterion that Container terminal operators consider when allocating berths in their terminal and criterion that shipping lines consider when requesting a berth in container terminal
3. Identify and rank the common factors consider by both Terminal operators and Shipping lines in berthing arrangements
4. Regression analysis and application of the rankings to the real world berth arrangement problem

Eight criteria have identified which consider by Transshipment container terminal operators when allocating for incoming main line container vessels. Finalized criteria were Berthing Pro-forma, Commercial aspects, Punctuality of Service, Service agreements and policies, Relationship and market power, Liner connectivity, Response to special requirements and Investment made in terminal. From the other aspect same eight criteria have finalized which consider by main container shipping lines when requesting for berths in transshipment container terminals. Finalized criteria were Berthing Pro-forma, Commercial aspects, Punctuality of Service, Service agreements and policies, Relationship and market power, Liner connectivity, special requirements and Investment made in terminal.

With respect to sub objective number two, Analytical hierarchy Process was used to compare each criterion and weight those by using the data collected from Container terminal operators and Shipping Lines.

As per the third sub objective of the research common aspects of criteria from both sides (i.e. From Terminal operators view and Shipping lines view) combined and again using analytical hierarchy process those were ranked by obtaining combined weights.

Regression analysis have carried out to observe the correlation of each criteria considered and to measure the impact of five main selected independent variables to the berth allocation process.

5.3. Conclusions

Derived model can use by both Transshipment container terminal operators and shipping lines when arranging berths. The reason to carry out a study to find out a common modal is that in competitive environment both parties should have mutual benefits rather considering individual short-term benefits.

For an example as practically experienced in the industry, if particular terminal focusing only commercial aspects when arranging berths to container vessels in long run they may lose other customers.

In order to use this common modal Terminals operators or shipping lines need to summarize voyage data under eight main criteria considered. Based on the summarized data they can easily assign weights for each and every incoming vessel awaiting to berth at their terminals.

5.4. Research Limitations

When carrying out this research following limitations are identified which unavoidable.

- Focusing area was limited to Transshipment container terminals and also for the Main line container shipping operations excluding feeder operation to be a specific and to reduce the complexity.
- When selecting samples ten Shipping lines and ten container terminal operators were selected based on pre-defined criteria. This is mainly due to reduce the complexity and inconsistency in analysis.
- Within this research focusing on the factors those are within control limits of terminal operators and Shipping Lines and factors commonly considered. There are some special considerations and criteria like government intervention, policies etc consider when allocating berths for container vessel those under special categories. Those kinds of situations are excluded from analysis since beyond control and not commonly in practice.
- When designing the pairwise comparison questionnaire, there was no available online website for create the questionnaire. So, questionnaire was manually designed. And due to the complexity in the questionnaire, personally advice professionals regarding how to respond to the questionnaire.
- For the weight calculation using AHP method, there is no standardized tool. In that case all the calculations were done manually.
- Selected professionals are busy with their schedules and it is little bit difficult to gather data. So personally, approached for them with the authorized manner.

5.5. Future research directions

In future research can focusing on to develop a detail mathematical modal which combining both aspects to use in berth allocation. Within this study only focusing on the base level by covering majority of criteria consider in berth allocation.

Research can expand to the all types of ports not only for container operations but other types of vessels as well and If consider container ships can include feeder lines which not consider within this study.

In future studies can focusing on developing a common modal and validating it as a win - win approach to the both parties by using mathematical approach.

5.6. Chapter Summery

This chapter summarized all the research findings with the recommendations for professional in world maritime industry, regarding the considerations when implementing the proposed decision support model frame work. And, the research limitations were pointed out with the overcome methods. Furthermore, as the conclusion, future research directions were recommended with reference to the current study. Finally, it can be concluded as berthing arrangement in container terminal is most critical and important activity and which should deliver mutual benefits as well. This common model will be an initial stage of modeling of the berthing arrangements in container terminal which may influence researchers in industry for further improvements and applications.

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Annex 01: Questionnaire to Shipping Lines

Development of conceptual model for main line container vessel berth allocation in a Transshipment Container Terminal

Part A

Q A-1: Please indicate the name of your Shipping Line? Click here to enter text.

Q A-2: Please indicate the routes currently served by your shipping line or by the alliance representing)

Route	West Bound	East Bound	North Bound	South Bound
Asia – North America	☐	☐	☐	☐
Asia- North Europe	☐	☐	☐	☐
Asia- Mediterranean	☐	☐	☐	☐
Asia- Middle East	☐	☐	☐	☐
North Europe- North America	☐	☐	☐	☐
Australia – Far East	☐	☐	☐	☐
Asia –East Cost South America	☐	☐	☐	☐
North Europe/ Mediterranean-East coast South America	☐	☐	☐	☐
North America- East coast South America	☐	☐	☐	☐

Q A-3: What is the shipping Alliance/s currently you are representing?

2M Alliance ☐

The Alliance ☐

Ocean Alliance ☐

Other ☐ please specify: Click here to enter text.

Q A-4: What actions/tactics you (or principle) have undertaken & practiced to maintain sailing schedules in contingency situations? (Please select)

Rearrange the order of ports ☐

Skip a port completely ☐

Employ cut and run tactics (Shutout the containers) ☐

Deploy other vessel to take over in combination with a delivery to a hub ☐

(Deploy additional vessel to take over lost volume)

Increase vessel speed

(Especially in Inter-continental legs) ☐

Any Other Please Specify: Click here to enter text.

Instructions (For fill part "B" & "part "C")

Here you are going to make a pair wise comparison of given criteria based on your value judgment on the level of importance of criteria consider when allocating berths for main line container vessels.

Using your value preference, please compare the importance of each criterion in the left hand side with the criteria in the right hand side in each row and mark one cell in a row according to the 1-9 scale.

Scale	Meaning	Explanation
1	Equally Important	Both criteria are equally important for the decision
3	Slightly Important	Judgment slightly favour towards the one element
5	Important	One element is important than other
7	Very Important	One element is very important than other
9	Extremely Important	One element is extremely important than other
2,4,6,8	Intermediate Values	Express judgments in between.

Example: If you think Berthing Pro-Forma Very Important than Commercial Aspects, then you mark 7 on the right-hand side as follows,

Criteria	**Extremely Important**		**Very Important**		**Important**		**Slightly Important**		**Equally Important**		**Slightly Important**		**Important**		**Very Important**		**Extremely Important**	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Berthing Pro-Forma	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial Aspects

Part B

Please make pair wise comparison based on relative importance of each pair of criteria in each raw and mark (X) in only a one box by considering point scale.

	Criteria	Extremely		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
B-1	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Service agreements and policies
B-2	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Relationship & market power
B-3	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-4	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-5	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-6	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-7	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-8	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Relationship & market power
B-9	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-10	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-11	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-12	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-13	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal

B-14	Relationship & market power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-15	Relationship & market power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-16	Relationship & market power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-17	Relationship & market power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-18	Relationship & market power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-19	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-20	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-21	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-22	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
	Criteria	**Extremely Important**		**Very Important**		**Important**		**Slightly Important**		**Equally Important**		**Slightly Important**		**Important**		**Very Important**		**Extremely Important**	**Criteria**
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
B-23	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-24	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-25	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-26	Liner Connectivity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Special requirements
B-27	Liner Connectivity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-28	Special requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal

Part C

Evaluation of Sub Criteria

Here you compare the important Sub criteria which directly affect to the Main Criteria.

Please Mark (X) by comparing relative importance of each sub criteria based on the level of influence on the your main criteria

Main Criteria: Berthing Pro-Forma																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
	9	8	7	6	5	4	3	2	1	½	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Window Arrival	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	ETA

Main Criteria: Service Agreements & Policies																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Terminal service Agreements (TSA)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Berthing policy of Terminal

Main Criteria: Commercial Aspects																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Contribution for the revenue of terminal	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Total Volume carrying by vessel(Domestic +Transshipment)

Main Criteria: Relationships & Market power																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Bargaining power of shipping line/Alliance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Status of relationship with Terminal

Main Criteria: Punctuality of Service																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Maintaining time schedules	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Tidal variations & vessel particulars
Maintaining time schedules	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Geographical Presence & routes operate
Tidal variations & vessel particulars	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Geographical Presence & routes operate

Main Criteria: Liner Connectivity																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Connectivity from Main/feeder vessels	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Connectivity of Inter Terminal Trucking & Export containers

Main Criteria: Special requirements																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Emergency requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Estimated time of readiness
Emergency requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Readiness of Pre Arrival declaration
Estimated time of readiness	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Readiness of Pre Arrival declaration

Main Criteria: Investment in Terminal																		
Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Return on Investment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Presence as Global Terminal operator

I certify that above information are perfect secured and only used for the Academic Purposes. Contact Information: Mobile (+94 715235968 / Email: pradeepk@slpa.lk)

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Annex 2: Questionnaire to Terminal

Development of conceptual model for main line container vessel berth allocation in a Transshipment Container Terminal

Part A

Q A-1: Please indicate the Name of your Terminal/Port: Click here to enter text.

Q A-2: Please indicate the shipping services currently calling to your terminal *(please select based on the area served)* (Please select)

Route	West Bound	East Bound	North Bound	South Bound
Asia – North America	☐	☐	☐	☐
Asia- North Europe	☐	☐	☐	☐
Asia- Mediterranean	☐	☐	☐	☐
Asia- Middle East	☐	☐	☐	☐
North Europe- North America	☐	☐	☐	☐
Australia – Far East	☐	☐	☐	☐
Asia –East Cost South America	☐	☐	☐	☐
North Europe/ Mediterranean-East coast South America	☐	☐	☐	☐
North America- East coast South America	☐	☐	☐	☐

Q A-3: What are the shipping Alliance/s currently calling to your terminal? (Please Select)

2M Alliance	☐	
The Alliance	☐	
Ocean Alliance	☐	
Other	☐	please specify: Click here to enter text.

Q A-4: Please specify the type of ownership of your Terminal:

Public or state runs Terminal	☐
Carrier Lease dedicated Terminal	☐
Terminals built and operation Terminal	☐
Carrier built and operation Terminal	☐
Joint venturing of the carriers and Terminal operators	☐

Q A4: Please indicate the number of Main Shipping Lines currently calling to your Terminal: Click here to enter text.

Instructions (For fill Part "B" & Part "C")

Here you are going to make a pair wise comparison of given criteria based on your value judgment on the level of importance of criteria consider when allocating berths for main line container vessels.

Using your value preference, please compare the importance of each criterion in the left hand side with the criteria in the right hand side in each row and mark one cell in a row according to the 1-9 scale.

Scale	Meaning	Explanation
1	Equally Important	Both criteria are equally important for the decision
3	Slightly Important	Judgment slightly favour towards the one element
5	Important	One element is important than other
7	Very Important	One element is very important than other
9	Extremely Important	One element is extremely important than other
2,4,6,8	Intermediate Values	Express judgments in between.

Example: If you think Berthing Pro-Forma Very Important than Commercial Aspects, then you mark 7 on the right-hand side as follows,

Criteria	**Extremely Important**		**Very Important**		**Important**		**Slightly Important**		**Equally Important**		**Slightly Important**		**Important**		**Very Important**		**Extremely Important**	**Criteria**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Berthing Pro-Forma	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial Aspects

Part B

Please make pair wise comparison based on relative importance of each pair of criteria in each raw and mark (X) in only a one box by considering point scale.

	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
B-1	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Service agreements and policies
B-2	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Customer service
B-3	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-4	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-5	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-6	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to the Special requirements
B-7	Berthing Pro-forma	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-8	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Customer service
B-9	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-10	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service

B-11	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-12	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to Special requirements
B-13	Service agreements and policies	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-14	Customer service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Commercial aspects
B-15	Customer service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-16	Customer service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-17	Customer service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to the Special requirements
B-18	Customer service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
B-19	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Punctuality of Service
B-20	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-21	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to the Special requirements
B-22	Commercial aspects	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-23	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Liner Connectivity
B-24	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to the Special requirements
B-25	Punctuality of Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal
B-26	Liner Connectivity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Response to the Special requirements
B-27	Liner Connectivity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal

B-28	Response to the Special requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Investment in Terminal

Part C

Evaluation of Sub Criteria

Here you compare the important Sub criteria which directly affect to the Main Criteria.

Please Mark (X) by comparing relative importance of each sub criteria based on the level of influence on the your main criteria

	Main Criteria: Commercial Aspects																		
	Criteria	Extremely		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-4	Vessel Size (Total containers to be handle)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Domestic container volume
C-5	Vessel Size (Total containers to be handle)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Market share growth rate
C-6	Vessel Size (Total containers to be handle)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Contribution for the revenue of terminal
C-7	Domestic container volume	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Market share growth rate
C-8	Domestic container volume	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Contribution for the revenue of terminal
C-9	Market share growth rate	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Contribution for the revenue of terminal

	Main Criteria: Berthing Pro-Forma																		
	Criteria	Extremely		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-1	Window Arrival	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	ETA

	Main Criteria: Punctuality of Service																		
	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-10	Maintaining time schedules	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Tidal variations & vessel particulars
C-11	Maintaining time schedules	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Geographical presence
C-12	Tidal variations & vessel particulars	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Geographical presence

	Main Criteria: Investment in Terminal																		
	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-17	% of Shares hold by shipping line	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Impact of Global Terminal operators

	Main Criteria: Customer service																		
	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-3	Shipping Line's establishment in industry	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Status of the relationship with shipping line

	Main Criteria: Service Agreements & Policies																		
	Criteria	Extremely		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-2	Terminal service Agreements (TSA)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Berthing policy of Terminal

	Main Criteria: Liner connectivity																		
	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-13	Feeder & main line connectivity	☐	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Connectivity of Inter Terminal Trucking & Export containers

	Main Criteria: Response to the Special requirements																		
	Criteria	Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	Criteria
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
C-14	Emergency requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Estimated time of readiness
C-15	Emergency requirements	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Readiness of Pre Arrival declaration
C-16	Estimated time of readiness	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Readiness of Pre Arrival declaration

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Part D (Additional)

Please rank based on the importance as per your own experience level

No	Statement	1 Disagree	2 Slightly Disagree	3 Slightly Agree	4 Agree	5 Strongly Agree
Berth Allocation						
1	Do you think that Berth Allocation is really important to achieve higher level of service reliability of your customers					
2	Have you deliver on arrival berthing facility for majority of incoming vessels at your terminal					
3	Do you have any conflicts/ restrictions when allocating berths for incoming main line vessels					

No	Statement	1	2	3	4	5
Berthing Pro-forma						
	Have you maintain fixed Berthing pro-forma for every main line customers in your good terminal when allocating berths as per the service agreements and policies					
	Have you strictly follow the berthing Pro-foma schedule in berth allocation process					
	Do you face any other circumstances where unable to bound to berthing pro-forma schedule but for other considerations beyond that which include in service agreements and policies					

No	Statement	1	2	3	4	5
Commercial Aspects						
	Is total container volume (T/S+ Domestic) to handle at terminal by particular incoming vessel make a big impact on berth allocation decisions					
	Is Market share growth rate of the particular service where vessel is deploying/operating really consider in berth allocation					
	Is Contribution for the revenue of terminal(Percentage of the container volume (TEUs) handle in terminal by considered shipping line) consider when allocating berths for their vessels					

No	Statement	1	2	3	4	5
Punctuality of Service						
	Do you consider the status of maintaining time schedules (Windows of leading ports and Terminals, Suez, Panama) of your incoming vessels' when allocating berths					
	Is Geographical presence & routes operate (East bound -West bound , North bound-South bound)make any importance in berth allocation process					
	Do you consider Tidal Variations, special requirements and vessel particulars when allocating berths					

No	Statement	1	2	3	4	5
Liner Connectivity						
	Does Berth allocation activity depends on the status of connection containers from other vessels/ yards					
	Does Connectivity of Inter Terminal trucking (ITT) & Export containers (Hinterland connectivity) considered as important factor in Berth allocation					
	Does service agreements and policies implies that the consideration of Connectivity of the Feeder Network & Main line vessels for berth allocation					

No	Statement	1	2	3	4	5
Investment in Terminal						
	Are there any shipping line/s having % of shares of your good terminal which makes an impact in berth allocation process					
	Do you believe that if powerful Global Terminal operator/s represent in your good terminal who operate their own vessels can make an big impact on berth allocation activities					
	Are there shipping lines who make an majority share of investments on terminal development and only consider the profits share as a return but not priority berth allocation for their vessels					

Annex 3: Output of the SPSS Analysis

Descriptives

[DataSet0]

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Berth_Allocation	30	3.70	5.00	4.3500	.34416
Berthing_Proforma	30	3.00	4.70	3.9400	.38650
Commercial_Aspects	30	2.00	3.70	2.5867	.50701
Punctuality_of_Service	30	3.70	4.70	4.0033	.28099
Liner_Connectivity	30	2.00	4.00	2.8367	.44449
Investment_in_Terminal	30	2.00	3.30	2.7867	.38032
Valid N (listwise)	30				

Descriptives

[DataSet0]

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Berth_Allocation	30	3.70	5.00	4.3500	.34416
Berthing_Proforma	30	3.00	4.70	3.9400	.38650
Commercial_Aspects	30	2.00	3.70	2.5867	.50701
Punctuality_of_Service	30	3.70	4.70	4.0033	.28099
Liner_Connectivity	30	2.00	4.00	2.8367	.44449
Investment_in_Terminal	30	2.00	3.30	2.7867	.38032
Valid N (listwise)	30				

Correlations

[DataSet0]

Correlations

		Berth_ Allocation	Berthing_ Proforma	Commercial_ Aspects	Punctuality_ of_Service	Liner_ Connectivity	Investment_ in_Terminal
Berth_Allocation	Pearson Correlation	1	.612**	.379*	.419*	.366*	.424*
	Sig. (2-tailed)		.000	.039	.021	.047	.019
	N	30	30	30	30	30	30
Berthing_Proforma	Pearson Correlation	.612**	1	.274	.084	.075	.363*
	Sig. (2-tailed)	.000		.143	.657	.692	.049
	N	30	30	30	30	30	30
Commercial_Aspects	Pearson Correlation	.379*	.274	1	.206	.463*	.053
	Sig. (2-tailed)	.039	.143		.275	.010	.782
	N	30	30	30	30	30	30
Punctuality_of_Service	Pearson Correlation	.419*	.084	.206	1	.120	.007
	Sig. (2-tailed)	.021	.657	.275		.526	.971
	N	30	30	30	30	30	30
Liner_Connectivity	Pearson Correlation	.366*	.075	.463*	.120	1	.284
	Sig. (2-tailed)	.047	.692	.010	.526		.128
	N	30	30	30	30	30	30
Investment_in_Terminal	Pearson Correlation	.424*	.363*	.053	.007	.284	1
	Sig. (2-tailed)	.019	.049	.782	.971	.128	
	N	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Regression

[DataSet0]

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Investment_in_Terminal, Punctuality_of_Service, Commercial_Aspects, Berthing_Proforma, Liner_Connectivity[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Berth_Allocation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.785[a]	.616	.536	.23431

a. Predictors: (Constant), Investment_in_Terminal, Punctuality_of_Service, Commercial_Aspects, Berthing_Proforma, Liner_Connectivity

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.117	5	.423	7.713	.000[a]
	Residual	1.318	24	.055		
	Total	3.435	29			

a. Predictors: (Constant), Investment_in_Terminal, Punctuality_of_Service,

Annex 4: Sample Berthing Pro-Forma of a container Terminal