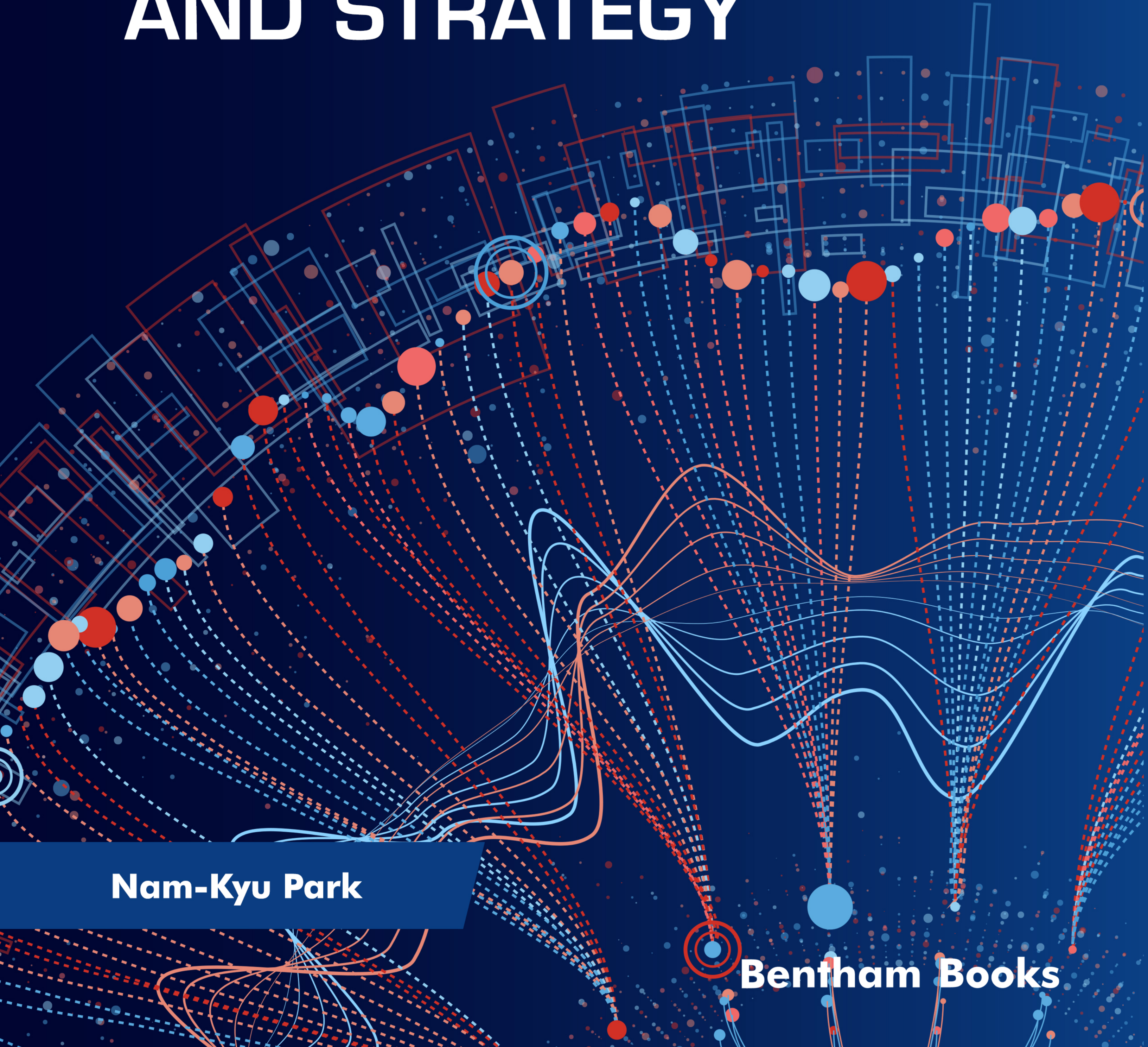
SMART PORT MANAGEMENT AND STRATEGY



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Smart Port Management and Strategy

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PREFACE

Although discussions on smart ports have been steadily unfolding, most of them have been organized around concepts and technology. This book has been described in terms of the design, operation and strategy of smart port to improve the capacity and productivity.

Smart port is known as economic entity that improves services by applying 4th industrial revolution technologies such as sense, IoT, AI, robot, big data, and 5G communication to the traditional port management field. This technology entrusts the work of humans to robots and AI to make full use of the new strategy. Furthermore, the emergence of these new technology is also affecting changes in design and management practices.

Smart port consists of four main areas like operation, energy, environment, safety and security. Energy, environment and safety are closely linked to port automation. The energy used in the automated terminal is electricity, and the resulting environment is naturally improved. In addition, since it operates without people, safety is guaranteed. Apart from energy, environment, safety and security, all that remain in smart ports is port automation with robotic equipment and digital platform.

Since digitization and automation are basic requirements for smart ports, terminal design, equipment specifications, the number of required equipment like Quay Crane, AGV and ASC *etc*. and the digital platform for PPI (Port Performance Indicator) emerges as important topics.

In 2021, advanced ports are trying to meet the standards of productivity, safety and environment by building an automated terminal. The United States, Netherlands, Germany and China have already built automated terminals to achieve the improvement of productivity, safety and environment. However, the degree of achievement of the technology is still ongoing. Even if the author himself cannot predict how much the technology will develop, he tries to explain the strategy, design and operation in order to pursue the supreme status that smart port aims.

In general, a smart port is defined as a port that uses technologies such as big data, AI, and IoT, but the author does not focus on technology itself. If you go through the eight themes in this book, you will find that this technique is naturally incorporated into each subject. Viewing the complex system of ports as a simple application of technology does not properly explain smart ports.

When IoT technology is applied to a truck, it automatically identifies which truck it is and where it is currently. If this is attached to the container, what is the temperature and humidity of the cargo loaded into the container? Has the container been shipped? It will help you figure out where the container is now. Such a technology has already been tested on its own and is entering the stage of practical use. This book deals with gates to which OCR, RFID, and sensor technologies are applied in Chapter 2, 3, and 6.

Big data technology is also applied in this book. Port performance measurement in Chapter 5 is impossible without big data. Analysis technology is also important for big data, but a social system that collects it should be the premise. Fortunately, this book has provided access to Port-MIS, which is owned by the Korean government, allowing millions of data to be collected and analyzed. In addition, the friendly TOC was willing to provide terminal operation data for three years.

Robotic technology is being applied to smart ports. In Chapter 2, AGV and ASC are robots applied to port operation. This book does not explain the mechanical properties of robots. These transport equipment and loading/unloading equipment are being deployed on the premise that they are supplied by specialized companies.

AI is a technology that allows machines to replace human thinking systems. It consists of various areas such as automated reasoning and inference, machine learning and deep learning, knowledge reasoning, representation and discovery, and natural language. This chapter 7 deals with the operating system of an automated terminal. AI technology that commands and controls automation equipment such as AGV, ASC, and remote control QC is applied. Since the purpose of this book is how to create a smart port that maximizes productivity, efficiency, and capacity, it does not deal with these unique theories concerning AI.

The layout of the smart port needs to be evaluated by various factors such as cost, capacity, productivity and congestion. Simulation gives insight into solving this problem. The validity of the terminal design, the validity of the required number of equipment, and the waiting time are verified only through simulation. In this book, I would like to introduce the method revealed through experience.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

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CHAPTER 1

Strategy of Smart Port

Abstract: Smart ports are defined from a variety of perspectives. Smart ports are automated, logistics optimization, energy-efficient, the eco-friendly and innovative port through the innovation of information technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI). Smart ports are expanding their boundaries to the city in order to strengthen the connection. Furthermore, smart ports organically connect all related resources by acting as a hub for information flow to collect, process, analyze and share data. We need deep insight into the question of what the future be like. This chapter aims to answer two questions: what is a smart port, and how are they prepared to become a smart port? What is the strategy for the smartization of advanced ports?

Keywords: Artificial intelligence (AI), Automated port, Eco-friendly port, Energy-efficient port, Internet of Things (IoT), Logistics optimization, Smart port.

1. INTRODUCTION

The port competitiveness was to attract more ships, cargo, and shippers until now. However, as the supply of ships overflowed and the recession continued, a new survival strategy was needed.

The trend of larger ships called “Megamax” is irreversible and directly impacts container ports. The enlargement of ships inevitably leads to an explosive increase in the volume of cargo that must be handled at the port. At this point, the reduction of terminal operating costs has emerged as a new concern for the port, and smart ports that combine ICT (Information Communication and Technology) such as big data and IoT (Internet of Things) are attracting attention as a solution.

Many experts have referred to the “Fully Automated Container Terminal” as a substitute that responds to the emergence of super-large ships. The fully automated container terminal is a port where all tasks are performed by automated machines and is operated through robots and intelligent computers.

Therefore, safer and more efficient operation is possible than human operation. The concept of a fully unmanned automated container terminal emerged long before the smart port was used universally.

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As the number of mega-ships continues to increase, the design criteria should be considered up to 25,000 TEU class ships when improving existing ports or constructing new ports. This means not just increasing the size of land but also having a stable terminal operation system (TOS), that is, a smart operating system.

The fully automated container terminal was chosen to satisfy the service demanded by shipping companies operating ultra-large container ships because the fully automated container terminal can increase productivity by 30% to 40% compared to existing terminals.

Recent issues surrounding the port are space constraints, degrading productivity, financial limitation, and the necessity of environmental protection, in addition to servicing mega-ships. It is a smart port that fits perfectly with this trend of the times. This is because the goal of smart ports is to efficiently operate ports without wasting space, time, capital and natural resources.

In addition to the advantages of reducing labor costs and port operation costs, the fully automated container terminal also uses eco-friendly equipment that uses electricity or battery without emissions such as greenhouse gases.

One of the backgrounds leading to the introduction of smart ports is the recent environmental change that requires sharing information between the logistics stakeholders. With the development of information technology, a large amount of information that was unimaginable in the past is gathering in ports. The issue of opening and sharing this information with shippers and port-related companies such as shipping agencies, terminals, and regional service companies has become a trend that determines the competitiveness of future ports.

2. THE CONCEPT OF SMART PORT

Smart ports have developed through the stages of U (Ubiquitous) Port, Intelligent Port, and Automated Port. Recently, the concept by PA (Port Authority) and researchers regarding smart port is defined as follows.

The HPA (Hamburg Port Authority) defines a smart port that not only achieves sustainable economic growth but also improves the quality of life by minimizing environmental impacts. HPA focuses on state-of-the-art digital intelligence to ensure a smooth and efficient operation for smart PORT concept. HPA uses sense technology, analysis, forecasting and information systems for increases in efficiency, economic growth, customers benefit while minimizing environmental impact (Hamburg Port Authority, 2021).

The Maritime and Port Authority of Singapore (MPA) suggested that smart port would use mobile technology and wireless connectivity to enhance communications, productivity, and maritime crew welfare in the Port of Singapore. Utilizing the technology of smart devices, sensors and IoT, MPA has tried the port to be a more interconnected port with high-speed network, innovative use of data analytics, and mobile solutions to enhance its overall competitiveness that will benefit all users and customers (The Maritime Executive, 2015).

The port of Antwerp is strategizing by separating the area of smart port, energy, and transportation. Smart port is defined as the application of block chain, augmented reality (AR), artificial intelligence (AI) and machine learning (ML) to the port to fully control and manage the port remotely (Port of Antwerp, 2021).

MedMaritime proposed that the smart port concept addresses three main types of issues related to operational, energy, and environmental aspects. They suggested 23 criteria and 68 key performance indicators (KPIs) for smart port operation. (MedMaritime SMART PORT, 2016).

Deloitte suggests a smart port is developing solutions to address the current and future challenges faced by seaports, including spatial constraints, pressure on productivity, fiscal limitations, safety and security risks and sustainability (Berns *et al.*, 2017). They divided the evolution of the port into four generation stages (Table **1.1**): The first generation port is a loading and unloading port until the 1960s. The second generation port is an industrial port until 1980s. The third generation port is a logistics and supply chain port (post 1980s). The 4th generation is the smart port after 2010. A true Smart Port will need to take advantage of its position in the supply chain to add value with the improved use of the data. They suggested that smart port would implement port terminal integration, port-city integration, integration of ports, and the wider supply chain.

Table 1.1. Port development phase.

	Port 1.0	**Port 2.0**	**Port 3.0**	**Port 4.0**
Operation	**Manned Operation**	**Semi-auto Operation**	**Fully Automated operation**	**Smart Operation**
Equipment control	Manned ASC	Auto ASC	Auto ASC	Remote control QC
	Manned QC	Manned QC	Manned QC	Auto RMGC
	Manned yard tractor	Manned yard tractor	AGV	AGV
	Manned shuttle carrier	Manned-shuttle carrier	Auto-shuttle carrier	Auto-shuttle carrier

CHAPTER 2

QC, ARMGC and AGV of Smart Port

Abstract: In order to build a smart port, the basic direction should be preceded. This chapter is related to the review of automated equipment introduced in smart ports. The subject of the review is STS (Ship to Shore), ARMGC (Automatic Rail Mounted Gantry Crane), and transfer equipment. Quay cranes (QCs) are equipment used to load/unload containers into/from ships on rails in the quayside area. QC types are divided into SHST (Single Hoist Single Trolley) and DHST (Dual Hoist Second Trolley). Depending on the number of pickup containers, they are also classified into twin and tandem. The work of QC is divided into work on the ship side and work on the AGV side. To overcome ship side handling, a remote control device is introduced in the 4th generation port.

ARMGC is a crane for yard work and is divided into CATC (Cantilever Automatic Transfer Crane) and ASC (Automatic Stacking Crane). In the ASC type, crane work can only be done at the end of the block. Most automation terminals such as ECT, CTA, LBCT, and BNCT use ASC type. However, the recently evolved ACTs deploy cantilever-type cranes for loading and unloading operations. Yangshan port phase 4, APMT, and RWG of Rotterdam use a mixture of CATC and ASC types. The reason they have used CATC is to speed up the transshipment volume.

Container transport equipment is classified into AGV (Automatic Guided Vehicle) and ALV (Automatic Lifting Vehicle). AGV is divided into diesel, electricity, and battery type according to the energy source. It is also classified according to whether it has a lifting function. Lifting AGVs are highly productive, so the 4th generation ports are introducing them.

Keywords: Automatic guided vehicle (AGV), Automatic stacking crane (ASC), Battery-Lift AGV, DHST, Quay crane, SHST.

1. INTRODUCTION

The problem to consider when trying to introduce ACT is the selection of equipment. Equipment to be selected includes QC (Quay Crane), ARMGC (Automatic Rail Mounted Gantry Crane), AGV (Automatic Guided Vehicle), and ALV (Automatic Lifting Vehicle or is called Shuttle Carrier). The selection of equipment should be outlined prior to infrastructure construction.

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There are two types of QC. The DHST type is a method that separates seaside and onshore work. It is common to use the technique that QC's ship work is manned, and land unloading work is done automatically. On the other hand, SHST is a method that makes ship and land operations consistent.

AGV is automated horizontal transfer equipment. There are also many options available. First of all, diesel oil, electricity, and battery are possible as energy sources for AGVs, so it is necessary to review them. In terms of AGV productivity, a review of lifting AGVs and non-lifting AGVs is required in advance. Furthermore, a comparison between the AGV and the shuttle carrier is required. Rotterdam's RWG operates a lifting and battery-type AGV, and LBCT operates a non-lifting and battery-type AGV. On the other hand, there are terminals that operate shuttle carriers. As such, each terminal introduces a different AGV type depending on the conditions.

The equipment that handles containers in the yard is RMGC. In general, the equipment used for ACT is ASC. However, with the recent advent of the 4th generation ACT, ASC and CRMGC are used in combination. This also depends on the strategy and situation of each automated terminal.

2. QUAY CRANE

The determination of the QC size is related to the size of the vessel entering the terminal and the 30,000 TEU ULCV (Ultra Large Container Vessel) that will appear in the future. As of 2021, the largest vessel is HMM's 23,964TEU class vessel, with length 399.9 m and width 61.5m, height above deck 33.2m, draft 14.5m.

According to the research (Park *et al.*, 2019), the dimensions of a 24,000 TEU ship is predicted to be LOA (Length of All) of 426m, breadth of 64m and summer draft of 16.8 m. The dimensions of 30,000 TEU container ships are predicted as 453 m LOA, 72.0 m beam and up to 17.3 m draught (Park *et al.* 2019). According to Alphaliner, the 30,000 TEU ship could be reached with dimensions of 425 m × 66.1 m (Alphaliner 2021). According to OECD (Organization for Economic Co-operation and Development) ITF (International Transport Forum) the dimension of a 24,000 TEU ship is expected to be 430m in length and 62.0 m of breadth (OECD/ITF, 2015).

In practice, the Out Reach of QC (Fig. **2.1**) is expressed as the number of rows that can be handled in the breadth of the ship. If the width of the ship is 62m, the number of rows can be converted to 24 by the formula **(2.1)**.

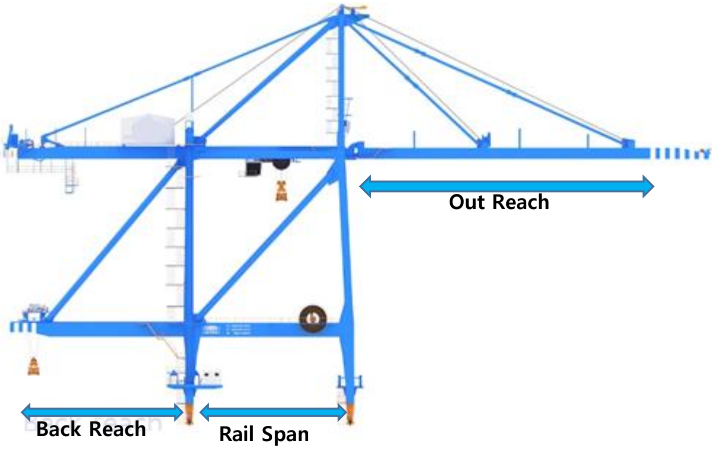

Fig. (2.1). QC cross-sectional view. Source: Author.

$$\begin{aligned} &Number\ of\ ship's\ rows = (length\ of\ ship\ breadth + \\ &the\ center\ of\ the\ ocean\ side\ rail\ to\ the\ berth\ line + \\ &the\ length\ from\ berth\ line\ to\ the\ fender + \\ &the\ ship\ angle\ of\ pitch)\ /(2.45\ x\ separation\ factor) \end{aligned} \tag{2.1}$$

The length from the center of the ocean side rail to the berth line is 6.5 m, the length from the berth line to the fender is 1.4 m, the width of container loading is 24 rows and 62 m, and the ship angle of pitch is 1.5° and 0.78 m. The sum of the value is 70.4 m total. The Out Reach of the QC to handle 24 rows of ships should be a minimum of 70.4 m for container ships under 22,000 TEU. If a 24,000 TEU ship calls at the terminal, the Out Reach of the QC should be a minimum of 73.0 m, respectively, as shown in Table **2.1**. If the forecast value is applied conservatively, the Out Reach should be 25 rows when 24,000 TEU class arrives.

Table 2.1. Ship breadth and Out Reach.

Case	Ship Capacity (TEU)	Ship Breadth (m)	Ship Rows	Out Reach (m) of QC
1	20,000	59	23	67.7
2	21,000	60	24	69.0
3	22,000	62	24	70.4
4	23,000	63	25	71.7
5	24,000	64	25	73.0
6	25,000	66	26	74.3
7	26,000	67	26	75.7

CHAPTER 3

Layout Design of Smart Port

Abstract: The layout design of smart port is evolving. With the introduction of the 4th industrial revolution technology, the productivity of the ACT (Automated Container terminal) is surpassing that of the conventional method. In this chapter, the author focuses on designing the layout of ACT of a case terminal. ACT area is divided into QC (Quay Crane) Set Back, QC Rail span, AGV handling area under QC, AGV road and working area, WSTP (Water Side Transfer Point), CY Block, LSTP (Land Side Transfer Point), support facility and gate facility. The data required for the ACT design is the operation data of the neighboring terminals. The operation data include the container dwell time, max stacking height, CY utilization ratio, working days per year, peaking factor and the throughput by export, import, transshipment. Furthermore, it is necessary to seize the ratio of container by full, empty, reefer, oversize, dangerous container type, TEU conversion ratio and gate transit time, *etc.* Here, we propose three types of ACT such as Y type, L type and U type. The process of designing these drawings, formula and parameters will be described.

Keywords: Automated port design, Terminal gate design, Terminal zone planning, Vertical block layout.

1. INTRODUCTION

In order to design the layout of ACT, it is necessary to understand the recent design trends of the advanced ACT. ACT opened in 1990, has evolved from a rudimentary level to a sophisticated level over the past 30 years.

The world's first automated terminal was the Thames Port in the United Kingdom. Construction began in 1982 and was in operation in 1990. There are two ASCs in the yard to realize relay operations. The outer truck reverses and enters the end of the yard for operation, while the inner truck enters the yard and performs the same operations as a conventional tire crane. This terminal only realizes yard automation.

The first-generation ACT is an ECT terminal. ECT opened DDN in 1993, and at this time, one light rail crane, which stacks up to two tiers in wire type, was placed per block in the yard, and the AGV was used for horizontal transportation for the first time. In the DDE opened in 1996, containers in the yard can be

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stacked in 3 tiers, and in the DDW opened in 2003, they can be stacked in 4 tiers. This shows that the ACT yard staking capacity is evolving. As of 2018, the loading capacity per berth of DDE and DDW was surveyed as 460,000 TEU (Ministry of Oceans and Fisheries, 2020). According to the 2018 performance, the productivity of ECT's first-generation terminal was 1,100 TEU per 1 meter, showing almost the same performance as that of the fourth-generation terminal (Ministry of Oceans and Fisheries, 2020).

The Port of Hamburg opened CTA in 2002. In order to increase the productivity of the quay wall, DHST was installed to separate seaside and landside cargo handling work. In addition, CTA installed two ARMGs per block to cross each other in order to increase yard productivity. With the performance of TOS (Terminal Operating System), the annual capacity per berth is reached 650,000 TEU.

After CTA in Hamburg, EUROMAX was opened in 2008. EUROMAX installed two ASCs of the same size per block to increase the productivity of the yard. The annual loading and unloading capacity per berth is 600,000 TEU, and the throughput per meter of berth is 2030 TEU, making it a highly productive terminal.

London Gateway Teminal (LGT) opened in 2013. A 70m (25 rows) outreach was installed to improve the QC performance, and a manned shuttle carrier was introduced for horizontal transport. The block was designed in 10 rows, and two ASCs of the same size were installed. In particular, it shows originality in designing a space between blocks so that an external truck can enter.

The recently opened RWG (2015), APMT (2015), Yangsan Phase 4 (2017), QQCTN (2017), and LBCT terminals (2017) are called fourth generation terminals. Except for LBCT, the 4th generation terminals use Lift-AGVs and show the special design that allows AGVs to enter by widening the gap between blocks to handle transshipment cargo.

In the fourth phase of Yangsan, the horizontal transportation adopts Battery-Lift-AGV, and the storage yard is vertically arranged, mainly based on two relays ASCs. In order to adapt to the 50% transshipment cargo (TS cargo), CRMG is used in some of the yard areas. Qingdao Automation Terminal with 10% TS cargo, adopts AGV, the vertically arranged yard, and two ASC for relay operations. Total 24 types of terminals have been operated by the automation system. ACT is operated in various ways, from the first generation to the fourth generation. Container terminals are divided into horizontal and vertical types according to the block arrangement.

ACT is classified into 4 types according to block layout and scope of automation (Table **3.1**). The terminals with full automated operation and vertical block arrangement are ECT Delta (Rotterdam), HHLA-CTA (Hamburg), Patrick (Brisbane), Toshima Pier East Side Container Terminal (Nagoya), Euromax (Rotterdam), APMT (Rotterdam), RWG (Rotterdam), LBCT (Long beach), QQCTN (Qingtao), Yangsan Phase 4 (Shanghai).

Table 3.1. ACT (Automated Container Terminal) classification.

Full Automation and Vertical Block	Semi Automation and Vertical Block
ECT delta, RWG, APMT, Euromax, (Rotterdam) HHLA-CTA (Hamburg) Patrick (Brisbane) Toshima (Tokyo) LBCT (Long Beach) QQCTN (Qingdao) Yangsan Phase-4 (Shanghai)	Wan Hai (Kaoshiung) APMT Virgine Antwerp Gateway, TTI ALGECIRAS (Total Terminal International Algeciras S.A.) Tercat (Terminal Catalunya, Barcelona) BNCT (Busan) London Gateway Terminal
Full Automation and Horizontal Block	**Semi Automation and Horizontal Block**
Yunhai (Xiamen) Nansha Phase IV (Guangzhou)	London Thames port, HIT 6-7 Pasir Panjang (PSA), Evergreen(EMC) PNIT, PNC, HJNC, HPNT (Busan)

Source: Author

The terminals with semi-automated operation and vertical block arrangement are Wan Hai (Taipei), APMT Virginia, Antwerp Gateway, Hanjin Algeciras, Tercat (HPH), Barcelona, BNCT (Busan).

The terminals with semi-automated operation and horizontal block arrangement are London Thamesport, Hong Kong International Terminal 6-7 (Hongkong), Pasir Panjang terminal (Singapore), Evergreen (Kaohsiung), and PNIT, PNC, HJNC, HPNT (Busan).

The terminals with full automated operation and horizontal block arrangement are Xiamen Yuanhai, Guangzhou Nansha Phase IV. Xiamen Yuanhai is based on the upgrade of the conventional RTG yard. Xiamen Yuanhai with non TS cargo, adopts AGV, the horizontally arranged yard, and two ASC for relay operations.

Guangzhou Nansha Phase IV has a transshipment ratio of 80%. The yard is horizontally arranged, the last yard uses a double cantilever RMG, and the remaining yards use a single cantilever RMG. The benefit of this is the ability to isolate automated and non-automated areas.

CHAPTER 4

Proper Terminal Capacity of Smart Port

Abstract: For futuristic planning of smart port, it is very important to measure terminal capacity considering service indicators such as ship waiting ratio, berth occupancy, yard occupancy, and truck turnaround time. The capacity of a port proposed by UNCTAD is divided into intrinsic capacity and proper capacity. The intrinsic capacity is calculated on the assumption that the unloading/loading of the ship is operated 24 hours a day for 365 days per year. On the other hand, for the proper port capacity, the utilization ratio of the quay crane, the berth occupancy, and the actual number of available workdays of berth as service level are considered in order to calculate appropriate port capacity.

This chapter explains the basic mathematical theory required to calculate the proper capacity of smart port considering service level. The proper service of the berth is determined by the ship's waiting rate. Ship waiting ratio and berth occupancy have a positive relationship. Suppose there are 4 berths providing constant service in berth, 60% occupancy and 10% ship waiting ratio are calculated as an appropriate service level. The yard's capacity depends on the yard occupancy of 60% and the turnaround time within 30 minutes of the external truck. This value varies depending on the circumstances of the terminal.

Keywords: Formula of terminal capacity, Little’s law, Markov chain, Port service level, Queuing theory.

1. INTRODUCTION

A port’s capacity is normally defined as the cargo volume that the port is capable of handling per year and is often expressed as throughput in TEU per unit length of wharf. It is generally desired to calculate proper port capacities for various ship and various cargo types under certain assumptions pertaining to overall port service (Agerschou, 2004).

The theory on the calculation of port capacity is based on the contents presented in “Berth Throughput” published in 1973 by UNCTAD and “Port Development” in 1985 (UNCTAD 1973, UNCTAD 1985). UNCTAD presents the calculation formula by reflecting the ship waiting time ratio. It can be seen that the main

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factors of the calculation formula are largely influenced by the number and the productivity of QCs and the ship's waiting time ratio. The ship waiting time ratio is expressed as the ratio of the waiting time and service time of the ship arriving at the port.

In order to measure proper port capacity, UNCTAD organizes the transport process within a port into several systems according to the movement route of cargo. The capacity of each subsystem determines the capacity of the entire port. In order to understand the proper port capacity with the service level, the queuing theory that mathematically expresses the ship's arrival, queue, service, and departure will be explained.

2. SERVICE LEVEL FOR PORT CAPACITY

Traditional norms of berth capacity depend on variables such as the number of berths, proper berth occupancy, working hours, cargo handling and transfer equipment, and available transit & CY areas.

$$C_b = N_b \times O_b \times t_{year} \times P \tag{4.1}$$

C_b: Berth capacity per year

N_b : $Number\ of\ berths$

O_b : $proper\ berth\ occupancy(\%)$

t_{year}: $days\ the\ terminal\ is\ operational\ per\ year = \frac{363 days}{year}\ x \frac{24\ hours}{day}$

$$P: Ship\ productivity\ at\ berth\ P = \frac{Q}{T_s} \tag{4.2}$$

Discussion is required on the proper berth occupancy ratio O_b in Formula 4-1. Shipping lines are the main client of a container terminal. They perceive the quality of the service provided in two ways: First, the total amount of charges or tariffs that shipping lines must pay every time their vessels call at a port. Second, duration of the call at port (Soberón, 2012).

Here, when the turnaround time of the vessel per container is the service level, the service level is expressed by Formula 4-3.

$$\frac{T_p}{Q} \tag{4.3}$$

T_p: Ship turnaround time at port
Q: Amount of cargo to be handled in a call at the port

The ship's turnaround time consists of the sum of the ship's waiting time and service time (Formula 4-4)

$$T_p = T_{sw} + T_{ss} \tag{4.4}$$

T_{sw}: Average ship waiting time at port
T_{ss}: Average ship service at port

Dividing both sides of Formula 4-4 by Q (LPC) yields Formula 4-5.

$$\frac{T_p}{Q} = \frac{1}{Q}(T_{sw} + T_{ss}) \tag{4.5}$$

Formula 4-6 is derived by reorganizing the right-hand side of Formula 4-5 by $\frac{T_{ss}}{Q}$.

$$\frac{T_p}{Q} = \frac{T_s}{Q}\left(\frac{T_w}{T_s} + 1\right) \tag{4.6}$$

Let's define the inverse function of $\frac{Ts_s}{Q}$ as P. P becomes the ship's productivity.

$$P = \frac{Q}{T_{ss}} \tag{4.7}$$

P: Ship productivity at berth (which is mainly influenced by the number and specifications of the cranes,operator skill)

Substituting ship productivity P into Formula 4-6 yields Formula 4-8. *i.e.* the ship's service level is determined by the ship's waiting ratio $\frac{T_{sw}}{T_{ss}} = \frac{\mathrm{E}(W_q)}{s} = \frac{\rho}{(1-\rho)}$ and QC productivity $\frac{1}{P}$. In other words, ship waiting ratio and berth productivity must be considered in calculating the terminal capacity.

$$\frac{T_p}{Q} = \frac{1}{P}\left(\frac{T_{sw}}{T_{ss}} + 1\right) = \frac{1}{P}\left(\frac{\rho}{(1-\rho)} + 1\right) \tag{4.8}$$

CHAPTER 5

Key Performance Indicators of Smart Port

Abstract: Traditional port management is carried out in three stages: planning, implementation and evaluation. In recent years, port management techniques have gone through steps such as real-time data collection, description, prediction, diagnosis, and prescription to adapt to the rapidly changing business environment. This chapter tries to make port performance indicators to solve the current problem using real cases.

These activities begin with port performance analysis. Firstly, performance indicators of the smart port will be proposed on the operational aspects that are relatively easy to measure. Operational indicators are composed of output, productivity, utilization and service indicators. Output (Production) indicators are measured ship throughput, berth throughput, yard throughput as the level of the business activity. Productivity indicators are measured ship productivity, crane productivity and yard productivity as the ratio of output to input. Utilization indicators refer to how intensively the terminal resources are used. They are measured berth occupancy, yard utilization, gate utilization, equipment utilization. Service indicators refer to customer satisfaction with terminal services to customers. They include ship turnaround time, truck turnaround time, container turnaround time, crane Intensity, and container dwell time.

Keywords: Output indicator, Port performance indicator (PPI), Productivity indicator, Service indicator, Utilization indicator.

1. INTRODUCTION

To properly manage ports, data on activities must be collected and analyzed. Management cannot be done without performance measurement. PPIs (Port Performance Indicator) can be classified as output (production), productivity, utilization, and service measure (Thomas, 2000).

Output indicators consist of the following questions:

- What is the number of calling ships in a terminal for unit time?
- What is the container throughput in a terminal for unit time?
- What is the calling ships on size class in a terminal for unit time?
- What is the size of calling ship in a terminal for unit time?
- What is the stacked containers in yard for unit time?

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Productivity indicators consist of the following questions:

- What is the quay crane productivity of the terminal for unit time?
- What is the GBP (Gross Berth Productivity) and NBP (Net Berth Productivity) of the terminal for unit time?
- What is land productivity?

Utilization indicators consist of the following questions:

- What is the berth occupancy of the terminal for unit time?
- What is the yard occupancy of full, empty, reefer, oversize and dangerous container for unit time?
- What is yard equipment utilization of the terminal for unit time?

Service indicators consist of the following questions:

- What is the ship waiting time, ship service time, the number of waiting ships and ship waiting ratio for unit time?
- What is the truck turnaround time of the terminal for unit time?
- What is the container turnaround time of the terminal for unit time?
- What is container dwell time by full, empty, refrigerator, oversize and dangerous type for unit time?

There are three steps to creating PPI. The basic data for PPI is collected from the PORT-MIS, which is managed by Port Administration, and TOS (Terminal Operation System) which is managed by the terminal operation company.

There are five types of data required for PPI analysis. The information of berth facility is collected by Table **A1**, CY facility is collected by Table **A2**, berth activity is collected by Table **A3**, CY activity is collected by Table **A4**, and gate activity is collected by Table **A5**. In order to reduce data bias, the data collection period is recommended for the latest 36 months.

The collected data from external entities are stored in the database after verification and classification. Finally, descriptive PPI, predictive PPI are generated based on the input data (Fig. **5.1**). Additionally, diagnosis the prescription analysis will be useful to improve the performance of the container terminal (Park *et al.*, 2020).

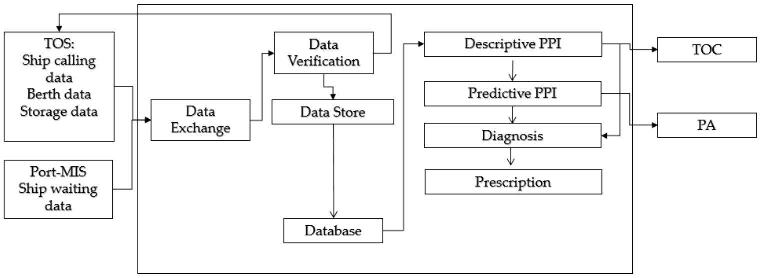

Fig. (5.1). PPI (Port Performance Indicator) system architecture. Source: Author.

2. PERFORMANCE INDICATORS OF SMART PORT

Defining the PPI, the ship's arrival-berthing-unloading/loading-departure process at berth is described in Fig. (**5.2**). When the ships arrive at port, the berth availability is to be checked before berthing. Especially, the berth scheduling should be reviewed in advance to ensure the availability of the berth.

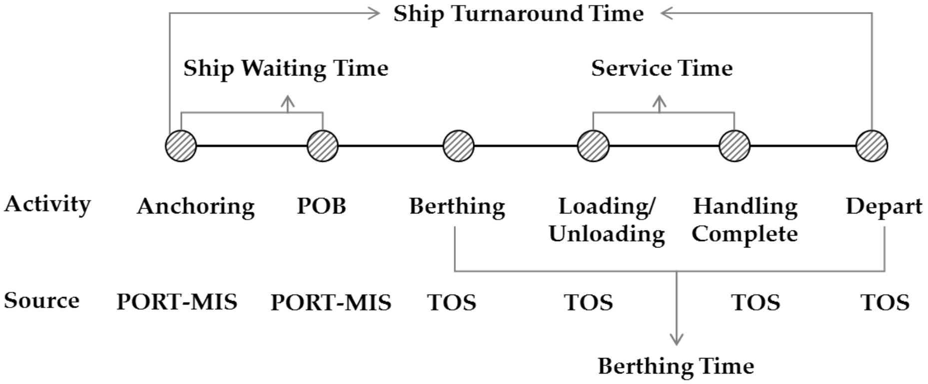

Fig. (5.2). Process of ship arrival-handling-departure. Source: Author.

If all berths are occupied by ships, then a ship has to wait in anchorage. When the berth is empty, the pilot will embark for the berthing. After the ship is alongside at berth, unloading and loading can be started. When unloading and loading are finished, the ship departs the port. In the ship arrival and berthing process, the indicators of ship waiting time, ship waiting ratio and ship turnaround time can be generated in the category of service.

In order to alleviate potential congestion and avoid cargo delivery delays to the end customer, TOC should improve the effectiveness of the terminal operations by monitoring PPI. TOC strives to achieve rapid unloading and loading as ships

CHAPTER 6

Simulation Model of Smart Port

Abstract: Most existing capacity models are based on the use of simulation, mathematical programming or queueing network models. Empirical formulas are used to calculate the berth, yard and gate capacities for a year. This method has often been used because of its simple measures of port capacity. However, empirical measures of port capacity have been criticized due to the volatility that can change the input value arbitrarily for the measure of port capacity.

Simulation models introduced in this chapter include berth, CY, gate and AGV operation. Berth simulation reproduces the process of ship call, waiting, berthing, unloading/loading, and departure of ships at the terminal through simulation. As a result of berth simulation, berth capacity, container throughput, the occupancy of berth, the number of calling ships, GBP, NBP, ship service time, the number of cranes per hour are derived.

Yard simulation keeps containers brought in from the gate, railroad, the mother ship, and feeder ship for container dwell time. After a certain period of time, they are taken out to the mother ship, feeder ship, gate and railroad. As a result of the yard simulation, the capacity of the yard and occupancy by container type are derived.

Gate simulation measures whether the number of designed gate lanes are appropriate, how many trucks are waiting at the gate and LSTP (Land Side Transfer Point), and what is the truck turnaround time.

AGV simulation proposes which method is appropriate through the performance of Lift-AGV and non-Lift-AGV. It also measures the AGV's performance on the number of blocks, which are the number of containers transported by AGV for an hour.

Keywords: AGV simulation, Berth simulation, Capacity simulation, Container terminal capacity, Gate simulation, Yard simulation.

1. INTRODUCTION

Simulation is the process of verifying whether the target performance can be achieved before port construction by imitating the phenomenon as it is. Simulation is essential in the process of planning a smart port. The performance measurement of ACT by simulation consists of four areas: berth, yard, gate and AGV.

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When designing a berth, the berth simulation helps predict whether the planned berth system, such as the specification of berth and QCs, will be able to handle the expected ships and cargo. As the berth simulation can measure the vessel waiting ratio by the expected ships and container throughput, there is an advantage in that the service level of the current berth system is precisely grasped.

The goal of the yard simulation is to measure whether the planned yard facility has the capacity to handle the expected volume. Since the capacity of the yard is determined by TGS, tier, dwell time, peak factor, *etc*., it is possible to verify the current planning system.

Gate simulation is to check the waiting situation of the truck entering the gate, the waiting situation when unloading/loading at the block, and the truck turnaround time.

The goal of the AGV simulation is to measure the performance of the AGV while checking the waiting time of each QC and RMGC connection when the planned AGV, QC, and RMGC are operated interconnected.

Implementing a simulation, it is important to check how well the simulation model represents the phenomenon. Therefore, before making a simulation model of the planned terminal, a terminal similar to the model to be made must be selected. If a similar terminal is selected, operational data for at least three years should be collected in order to prevent data distortion.

2. BERTH SIMULATION MODEL

2.1. Introduction to Berth Simulation

There is a limit to calculate sensitivity analysis of PPI like berth capacity, ship waiting ratio, service time, GBP/NBP and berth occupancy according to Formula. The Formula is difficult to answer the following questions.

- How does PPI change as the number of inbound vessels increase?
- How does PPI change as the lifts per call increase?
- How does service time change as the number of QCs increase?
- How does PPI change as the productivity of QCs increase?
- What are the optimal conditions for maintaining a 10% ship waiting ratio?

The above question can be solved only by a simulation technique. Simulation is the use of a probability distribution to accurately describe a phenomenon in a computer program.

2.2. Data Analysis for Berth Simulation Model

For the calculation of container terminal performance, first of all, the simulation model for ship operation at berth is to be developed. This simulation model is based on the actual data collected from container terminals. The analysis of real data makes it possible to prove the validity of this model.

The data for analysis includes the ships' arrival time interval, container handling times per ship the LPC (Lifts per Call) per ship and the number of assigned QCs per ship. The simulation model produces the following outputs: ship's waiting ratio, berth occupancy, the number of cranes per ship, the throughput per berth and average service time.

Data collection - All input values of parameters within each segment are based on data collected during the period (Table **6.1**). The main input data consist of ship inter-arrival times, lifts per ship call, the number of allocated QCs per ship call and QC productivity.

Table 6.1. Source data for a case study.

Sequence	**Ship name**	**Ship capacity (TEU)**	**Ship berthing Time**	**Unloading start time**	**Unloading end time**	**Loading container (20/40)**	**Unloading container (20/40)**	**QC working hours (Gross/Net)**	**GBP/NBP (moves)**	**Number of QCs**
1	REVEREN*	932	01-01 05:12	01-01 08:21	01-01 19:50	269/211	261/182	12.2 /11.5	78.3/82.8	2.6
2	PAAV*	998	01-01 12:24	01-01 12:24	01-01 17:23	30/68	44/90	5.2/4.2	49.2/61	1.9
:	:	:	:	:	:	:	:	:	:	:
1092	HEUNGA*	1,785	15-31 18:00	15-31 19:32	01-01 08:35	173/252	253/258	14.1 /13/1	67.3/72.5	2.7

Source: Author

Inter-arrival times of ships: The inter-arrival time distribution is a basic input parameter that has to be inferred from the observed data (Table **6.2**).

Table 6.2. The observed data of inter-arrival time.

Ship Name	**Berthing Time**	**Inter Arrival Time (hours)**
REVEREN**	2019-01-01 5:12	-
PAA**	2019-01-01 12:24	7.20
HYUND* COL**	2019-01-01 18:42	6.30
COSC* ROTTERD**	2019-01-02 8:12	13.50
:	:	:

CHAPTER 7

Digitalization of Smart Port

Abstract: To implement a smart port, a digital platform should be established. The digital platform is the integrated software, database, hardware and communication used to streamline business operations. This chapter intends to review the information-sharing model and TOS (Terminal Operation System) for TOC (Terminal Operation Company).

Information from external organizations is essential for smoothing the operation of the container terminal. The terminal operating system consists of a planning system, automatic control system (ACS), a management system and business support system and a business support package. The planning system includes berth planning, ship planning, yard planning, and resource planning plan.

ACS has the objective to ensure efficient operations of the automated equipment and to maximize the productivity of the entire terminal. This includes the operation of QCs, AGVs, ARMGCs as well as the automated container yard. The objective comprises maximization of operation efficiency, minimization of empty travel of ARMGC, satisfying scheduled due time and spreading workload among blocks and among QCs. Subsequently, the different modules of the planning system and the Terminal Control System will be described.

Keywords: Automatic terminal operation system, Berth planning, Information exchange model, Information sharing platform, Optimizer, Ship planning.

1. THE INFORMATION EXCHANGE MODEL

1.1. Information Exchange Model for Export Cargo

The shipping company informs the shipper of the ship calling schedule. The shipper applies for a booking to the shipping company according to the calling schedule. After determining the possibility of shipment, the shipping company sends a confirmation of shipment reservation (called Booking Prospect) to the shipper. The shipping company orders the empty container transport request on the shipper's booking to the carrier.

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The carrier picks up empty containers with seals stored in CY (Container Yard) or ODCY (Off Dock Container Yard) through dispatch instructions and he goes to the shipper's warehouse. The cargo is vanned into the container at the shipper's warehouse, sealed, and brought into CY.

The result of empty container transport is notified to the shipping company and the shipper. Prior to bringing the container cargo into CY, the carrier sends COPINO (Container Pre-Notification message) to the TOC (Terminal Operation Company).

TOC establishes a yard plan according to booking prospects received from the shipping company. Upon receiving COPINO from the carrier, TOC compares its accuracy with the booking prospect. If there is no difference between the two types of information, the cargo is brought into the TOC, but if there is a difference, the information is corrected and then brought into the TOC.

Upon receiving the COLDT (container shipment schedule list) and MOVINS (container loading instruction) from the shipping company, the TOC prepares the shipment plan and loading schedule.

Upon completing loading, the TOC reports the loading results to the shipping company, while the tally man reports the inspection results to the shipping company. The shipping company compares two types of information received from the TOC and the tally. For the tally to do the inspection, the TOC delivers the Manifest to the tally, and the tally registers this information in the tally system.

Upon completion of the shipment, the shipping company submits a declaration of ship departure to the Port Authority, the Customs, and the Immigration office for obtaining permission.

Shipping companies must request tugboats and pilots for ship departure and report cargo information to the Customs.

The information exchange system diagram of export cargo is shown in Fig. (**7.1**).

1.2. Information Exchange Model for Import Cargo

Before the ship arrives in port, the shipping company and TOC discuss the sailing schedule and berth schedule. A sailing schedule has a list of ships including the voyage number for each call, the ETA (Estimated Time of Arrival) and ETD (Estimated Time of Departure) and the ports of calls. A berth schedule is a total time required to serve vessels.

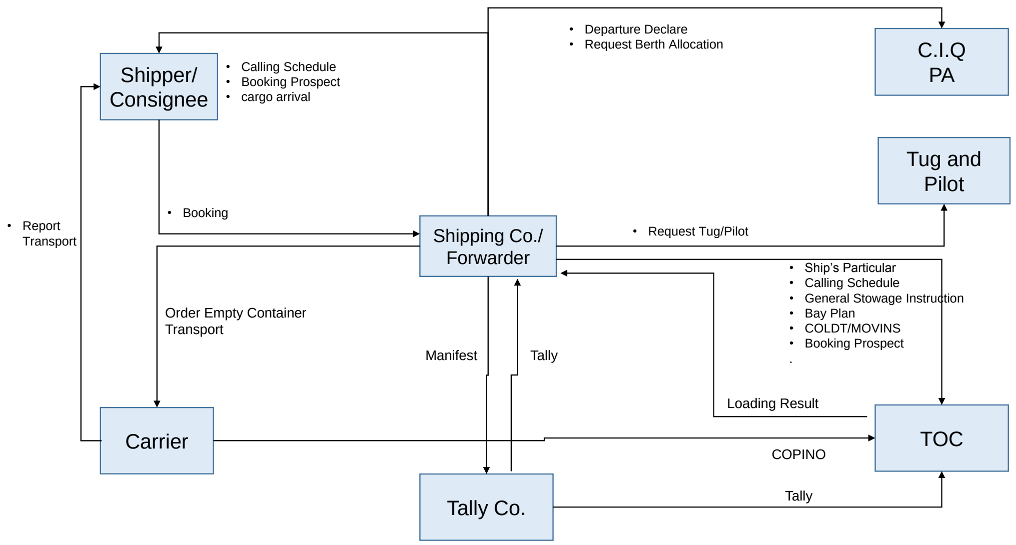

Fig. (7.1). Information exchange model for export cargo. Source: Author.

Afterwards, the shipping company applies for berth allocation to Port Authority, which notifies the shipping company of the result of the berth allocation.

Prior to the ship's arrival date, the shipping company sends an Arrival Notice (A/N) to the shipper. Arrival Notice is an international shipping document issued by ocean freight carriers/agents to consignees to inform about cargo arriving at destinations.

The shipping company receives the Bayplan and Manifest *via* E-mail from the previous port and sends this information to TOC by EDI or E-mail. Bayplan is a map of a storage bay in a ship, used to determine where various containers will be placed. Manifest is a transport document that is to aggregate the contents of BL on a ship-by-ship basis. A manifest has details like consigner, consignee, number, origin, destination, value, which is furnished to the Customs.

The ship's arrival schedule is transmitted to the transport carrier and the shipper/forwarder by the shipping company.

The shipper allocates CY or warehouse in the Manifest and sends it to the shipping company through fax, e-mail, or the Web, which is to use a service on Internet infrastructure. The shipping company receives the CY allocation request and checks its legality. The shipping company that has prepared the assignment list must report the Manifest with the place of disembarkation to the Customs.

CHAPTER 8

Economic and Financial Analysis of Smart Port

Abstract: Economic and Financial analysis can be done from two perspectives. The first point of view is that of the public sector, that is, the central government or the Port Authority. The second view is the terminal operation company (TOC).

This chapter deals with whether the smart terminal has economic and financial feasibility in two respects. It is important to have economic and financial feasibility under what conditions from two perspectives. The process of economic analysis from the public point of view and the process of financial analysis from the private sector are different.

As a result of economic analysis from the perspective of the public sector, the volume at the break-even is from about 570,000TEU of the five berths to 600,000TEU of two berths with a 2.96% discount ratio.

As a result of financial analysis from the perspective of the private sector, the volume at the break-even is from about 603,000TEU of the five berths to 633,000TEU of two berths with a 4.5% discount ratio.

Keywords: BEP, Cost Analysis, Economic Analysis, Financial Analysis, NPV.

1. INTRODUCTION

This chapter deals with the economic and financial issue of the automated terminal. The investment can only be made by securing economic and financial feasibility from an investor's point of view. There will be a discussion on investment items and benefit items from the public point of view.

From the perspective of the terminal operator, the discussion of cost items and revenue items develops. Financial analysis is performed for the purpose of comparing the investments and expenses and the revenue recovery (Castro-Santos *et al*., 2008).

After discussing the problem-solving method from two perspectives, economic and financial analysis is attempted through a case study. The subject of the case analysis is an automated terminal with a length of 350 m and a width of 600 m per berth with 5 berths (Fig. **8.1**).

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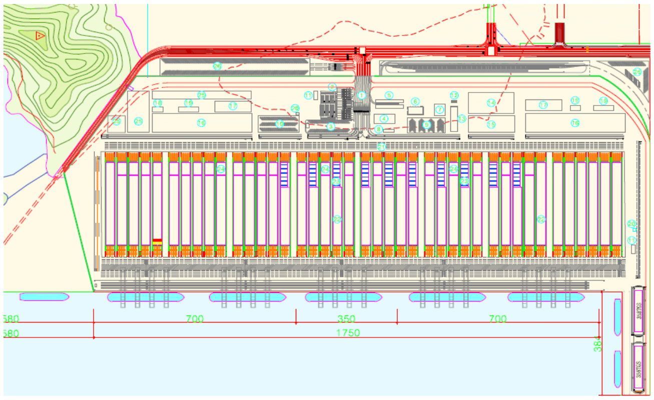

Fig. (8.1). Layout of ACT in a Case Terminal. Source: Author.

The economic and financial analysis depend on the size of the terminal. This is because the economy of scale comes into play. The analysis is different between the case of 5 berths and the case of 2 berths.

Port stakeholders have their own opinions on the capabilities of the terminal. Terminal operators try to calculate at least annual TEUs to survive financially. Public institutions try to calculate the rent to recover the investment cost. This chapter is an attempt to address these issues.

2. ECONOMIC ANALYSIS FROM THE PERSPECTIVE OF PUBLIC

The procedure of economic analysis is as follows:

1st step is to identify total investment, including investment cost and operating cost.

2nd step is to identify total revenue, including rent and port facility usage fees.

3rd step is to identify benefits including TOC added value and non-TOC added value and shipping company benefit.

4th step is to calculate net cash flow from the financial perspective.

5th step is to calculate net cash flow from the economic perspective including the dredging cost, the construction cost of the access road to the terminal, the cost of CY site development work *etc*.

6th step is to calculate the present value as investment cash flow, operating cash flow, and financial cash flows.

7th step is to calculate sensitivity analysis by the handling volume and the rent.

2.1. Premises of Analysis by the Perspective of Public

West Container Terminal in Busan New Port are selected as case terminal. The starting point for analysis is January 1, 2020. Construction investment would be completed by June 30, 2019.

According to Article 51 (2) 1 of the General Guidelines for the Preliminary Feasibility Study of the Ministry of Strategy and Finance, the terminal operation period shall be 30 years.

The financial discount rate is 2.96% by adding the business risk compensation rate (1%) to the yield of the 5-year Government bond (1.96%).

The consumer price inflation is 1.39% by applying the average inflation rate for the past 7 years. The mean value excludes the maximum and minimum values.

For the calculation of cost and benefit items, the preliminary feasibility study of the port sector project of the Korea Development Institute is applied.

The interest rate on borrowings is 3.16% by applying the weighted average of the interest rates on bonds issued by Busan Port Authority over the past 10 years.

The useful life of superstructure construction is as follows: pavement construction is 15 years, mechanical equipment is 20 years and electrical, and communication facilities is 20 years.

Depreciation is carried out using the straight-line method. Reinvestment and residual value consider the inflation rate after the end of useful life.

There is no equity investment, and the entire amount is borrowed from financial institutions. Repayment of borrowings shall be the balance after deducting interest expenses out of the annual rent and port facility usage fee income. The effect of VAT (Value Added Tax) is ignored, and the transaction is regarded as the supply price. Rent is calculated based on 40% of the quay wall and 60% of the TGS.

Economic analysis from the public point of view is implemented based on benefits and investment operating costs.

$$\text{NPV} = \sum_{n=1}^{N} \frac{B_t}{(1+r)^n} - \sum_{n=1}^{N} \frac{I_t}{(1+r)^n}$$

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SUBJECT INDEX

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