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Operations Management of Seaport Terminals in the Global Logistics Environment

Graduate School of Economics, Nagoya University

Academic Advisor: Professor NEMOTO Jiro

Name: YANG Wenhe

Operations Management of Seaport Terminals in the Global Logistics Environment

by

YANG Wenhe

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1 INTRODUCTION

1.1 Research Background and Motivation

Since the 1950s, the amount of international trade has continuously grown, with an especially tremendous increase during the last two decades. It is known that this phenomenal growth was triggered by the realization that countries' economies benefit from trade, which increases overall well being worldwide (Pierre, 2013). A key feature of the dramatic growth in trade since the mid-1980s has been the emergence and expansion of vertically integrated production networks, which now characterize a wide range of manufacturing industries from daily necessities to high-value products (Pitigala, 2009). An increasing number of companies are operating in the global marketplace via both global sourcing and global production. Despite the financial crisis of late 2007-2008, the dollar value of world merchandise has recovered, as exports exceeded 18 trillion dollars in 2014, the value that is approximately 9.6 times that of thirty years ago. Additionally, China's international trade volume (including both imports and exports) is approaching the US's 2011 trade volume and exceeds the US's 2013 trade volume.

With the growth of international trade, efficient and cost-effective transportation systems that link global supply chains have become vastly important to the economic development and prosperity. The Council of Supply Chain Management Professionals (previously the Council of Logistics Management) defines "logistics" as follows:

> *Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements.*

Based on the definition of "logistics", "international logistics" can be defined as the process of planning, implementing and controlling the flow and storage of goods, services, and related information from a point of consumption *located in a different country* (Pierre, 2013).

Generally, maritime and air transport are the main transfer modes used to transport goods among countries and regions. With the rapid increase in the world trade, the volume of the international maritime trade has increased accordingly. The increases in world merchandise exports and the world seaborne trade's cargo loads are shown in Figure 1.1. In 2012, the volume of the international seaborne trade reached more than 9 billion tons. Eighty percent of global merchandise trade by volume is carried by sea and handled by ports (UNCTAD, 2013).

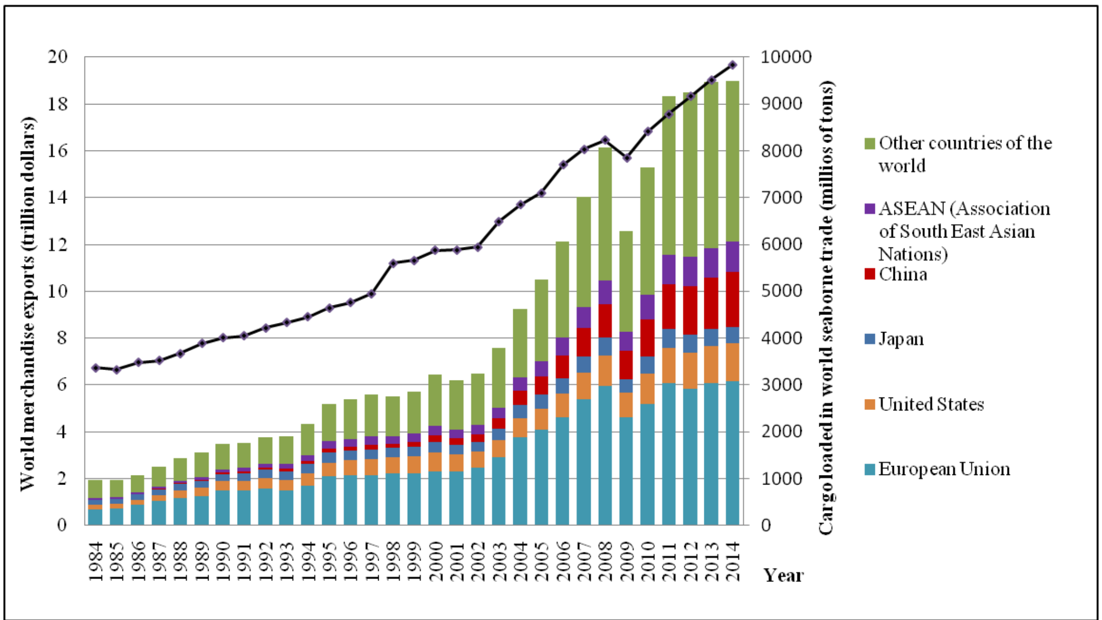


Figure 1.1: Growth of international trade and sea cargo

(Data Source: (1) World Trade data: World Trade Organization, Statistics database: Time series, http://stat.wto.org/StatisticalProgram/WSDBViewData.aspx?Language=E (2) Maritime Cargo data: UNCTAD, Review of Maritime Transport, http://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx)

For maritime transport, most of the cargo transported in ocean-going vessels around the world today can be classified into the types set forth below, which are based on the various types of goods that are transported (Murty et al., 2005; Takakuwa, 2012):

(1) Bulk shipping of huge quantities of commodities such as liquid bulk cargos (oil,

gasoline, liquefied natural gas (LNG), liquefied petroleum (LPG), etc.) and dry bulk cargos (grain, iron ore, coal, etc.).

(2) Containerized shipping in which a variety of goods are packed into standard-size steel containers that are shipped on vessels.

(3) Heavy machinery/automobiles, which are transferred by specialized vessels.

The type and proportion of the most common types of cargo carried by sea in 2012 are shown in Figure 1.2. Due to their large volume and heavy weight, bulk cargo is usually carried by from the country of origin to the country of destination by tramper vessel, whereas container cargo is usually carried by container ship, which is a regular liner ship that travels and temporarily stays at terminals along the shipping route.

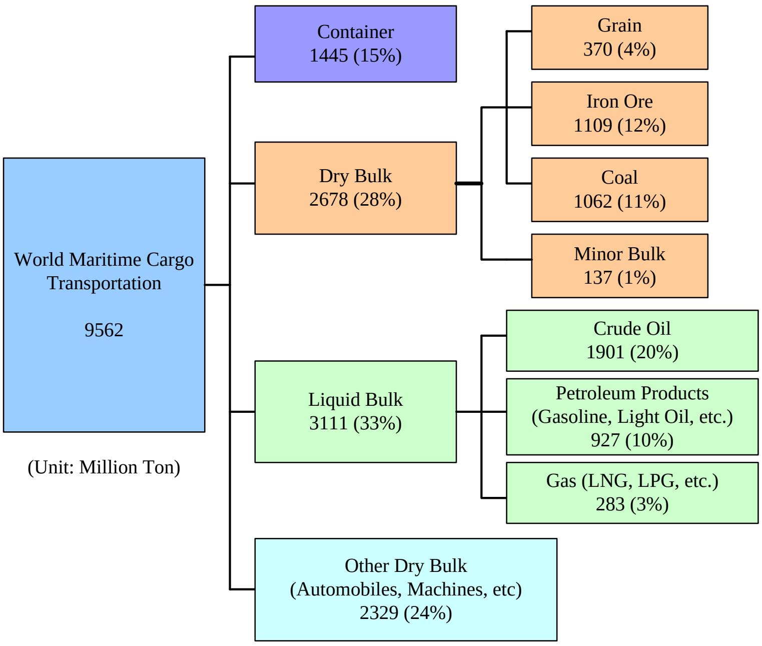


Figure 1.2: Most common types of cargo carried by sea

(Data Source: The Japanese Shipowners' Association, http://www.jsanet.or.jp/data/pdf/2014data30-1.pdf)

Containers are steel boxes sized 20×8×8.5 (called 20-ft containers; all measurements are in feet) or 40×8×8.5 (called 40-ft containers); alternatively, they are specialized, slightly larger boxes (Murty et al., 2005). One 20-ft container equals one twenty-foot-equivalent unit (TEU), which is the standard unit both for counting containers of various capacities and for describing the capacities of container ships at terminals, whereas one 40-foot container equals two TEUs (OECD, 2002).

Containerization was one the most important 20th-century transportation technology development in that it made mechanized handling possible, thus facilitating the acceleration of the globalization process that occurred after the 1960s. The wide use of containers has greatly improved handling efficiency and reduced costs. Because of advantages that include less packaging, less damage to goods and improved productivity, finished consumer goods are usually transported in containers on deep-sea container ships (Kemme, 2013). Furthermore, containerization has facilitated the regional and global integration of transport and value chains (Ducruet, 2013). Transfer efficiency is proceeding through vessel specialization and enlargement, both of which are also accelerating seaport construction and reforms.

Seaports are historic, commercial and infrastructural assets that form the backbone of national and regional economies (Alderton, 2008). With the rapid increases in international trade, container throughput and the ton base of the cargo handled by seaport terminals each year have become the standard measure of national strength. Both governments and terminal operators have correspondingly increased their attention and efforts devoted to strengthening port functions and improving port efficiency (Yang et al., 2011).

1.2 Problems Statement and Research Objectives

Operations function, i.e., the creation of goods and services, is a necessary function for organizations that seek to survive and evolve. *Operations management* is an area of management concerned with overseeing, designing, and controlling the process of production and redesigning business operations in the production of goods and services (Heizer and Render, 2014). From an operations-management perspective, seaport terminals can be seen as organizations that create services by generating and utilizing the inputs that they manage, which include the berth, the yard, the gate, the cargo-handling equipment, the staff, information, and other resources. The administrative and operational functions of the seaport terminal provide services that support ocean vessel transportation and manage import/export cargo by engaging in government-permitted temporary stocking.

Furthermore, information and communication technology (ICT) such as the Internet, electronic data-interchange (EDI) processing, mobile computers, wireless LANs, differential global positioning systems (DGPS) and electronic tagging technology, etc., are used to construct and realize the functions of assistance and support systems, both of which are widely used to support international logistics in terms of information exchange and processes control. The main purpose of using ICT systems for maritime operations management is to provide a total picture of what is happening as it happens, which was once impossible because of the vast complexity of such operations.

The lead time for customs clearance of import cargo and the ship handling time in the terminal are considered key indicators to evaluate the seaport service rates that influence which ports of call are chosen by shipping companies. Therefore, to meet global-logistics needs and facilitate international competitiveness, the problem of how to organize and generate inputs to make seaport-terminal operations both effective and efficient is regarded as an important issue.

To study the problem set forth above, the research presented in this dissertation has the following three objectives:

Objective One: to clarify the effect of the application of ICT in the areas of customs clearance and terminal operational control.

International trade transactions involve a very large number of documents, which provide certificates and instructions via trade-cargo information. Customs is the governmental authority that is responsible both for collecting duties and for controlling the flow of goods (including animals, transportation, personal effects, and hazardous items) into and out of a country. Therefore, import cargo receives documented permission to pass from the national customs authority so that it can enter the country; similarly, export cargo receives permission to leave the country. It is believed that both the convenience of submitting to these procedures and the clearance lead-time of import cargo in the seaport are improved by utilizing and integrating ICT systems. That said, because cargo-handling equipment typically includes quay cranes, yard cranes (such as transfer cranes or straddle carriers), vehicles and related operation processes in the container terminal that are controlled and supported by the ICT system, the detailed processes of the system's instructions and the data recorded need to be clarified for further analysis. Therefore, the first objective is to study the effect of ICT system application on improving seaport terminals' operations in the areas of administrative and operational functions.

Objective Two: To find a method to analyze and generate the data based on the record from a terminal operating system.

Given the vast, complex and dynamic interactions among the various handling, transportation, and storage units, ICT systems are widely used to assist and support seaport terminals' operations. Through the terminal operating system, operation instructions are given to the container-handling equipment and after the operation is complete, the latest container information is updated to the system. Meanwhile, a large amount of the tracking data is recorded in the system during daily operations, which requires that a solution be analyzed and used to capture the feature of the system. Therefore, the second objective is to process and analyze the system data to capture the system features and obtain the input data for a simulation model.

Objective Three: to design and evaluate the handling-equipment allocation problem on a container terminal.

The total volume of containers handled is expected to continue increasing in the future. Thus, container terminals are continuously challenged to increase their throughput capacity. To increase operating profit and satisfy customers, container terminals are required to serve ships as quickly as possible despite limited resources such as berths, yard stocks, and cargo-handling equipment. The problem of cargo-handling equipment allocation is referred to as one of the terminal's main control problems. Because it would be prohibitively costly and difficult to perform the experiment with an actual port system, a simulation model was constructed to test solutions to the problem. Therefore, the third objective is to build a simulation model to evaluate and analyze a cargo-handling problem in the terminal.

1.3 Structure Overview

The framework of the study is shown in Figure 1.3. This dissertation is organized as follows:

Chapter 2 presents a general overview of the main issues related to terminal planning and control, and it illustrates the method used in this dissertation, i.e., the discrete-event simulation. Steps for building the simulation model are introduced.

Chapter 3 presents a two-part review of the literature. First, methods of modeling and analyzing the problem of terminal design and the allocation and optimization of cargo-handling equipment are reviewed. Second, the literature on ICT application in both the seaport terminal and other logistics systems for operational analysis is surveyed.

Chapter 4 presents the ICT application in the seaport terminals. The effects of the two types of systems—i.e., the customs-clearance system and the terminal operating system—are clarified and examined.

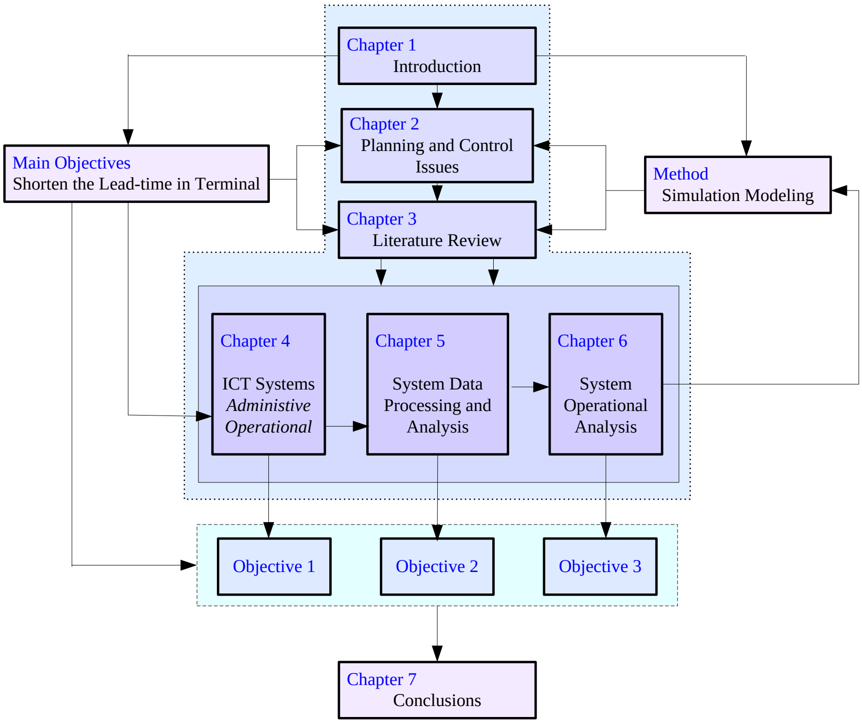


Figure 1.3: Framework of the study

Chapter 5 develops a VBA program for analyzing and processing the data extracted from the ICT system. Additionally, a simulation model is developed by applying the generated data to validating the processed data and analyzing the handling system.

Chapter 6 uses a simulation model to treat the performance analysis of a terminal. Scenarios involving an allocation policy for cargo-handling equipment are examined and compared by performing simulation experiments.

Finally, chapter 7 presents the conclusions of this dissertation and the suggestions for further research.

2 RESOURCE-PLANNING AND CONTROL ISSUES IN SEAPORT TERMINALS

2.1 Introduction

The *operations function*, i.e., the creation of goods and services, is a necessary function for an organization that wants to survive and evolve (Heizer and Render, 2014). Seaport terminals are the ship/shore intermodal interfaces that provide logistics services in the maritime transport industry. In today's highly competitive global logistics environment, terminals have a pressing need to effectively organize their limit resources (inputs) in a manner that improves the efficiency of their operations, thus enhancing their international competitiveness with their speedy service.

However, effectively designing, directing and controlling processes that improve service with limit inputs is a different problem because of the terminal system's complexity and randomness. Several types of handling equipment and transporters are employed in the terminal. The terminal's resource-planning and control issues for improving terminal system performance can be divided into three levels: terminal design, operative planning, and real-time control (Günther and Kim, 2006).

In addition, the high-performance modeling and analyzing functions enabled by computer simulation makes it one of the most advanced and powerful tools in system analysis. The simulation approach can enable both designers and analysts to foresee a system's behavior in both normal and emergency situations (Azadeh and Maghsoudi, 2010). Furthermore, support from the simulation results, the optimal number of recourses (space, number of equipment, human operators, etc.), proper resource-dispatching rules and acceptable workload levels can be decided by the system designers.

In this chapter, Section 2.2 presents the seaport terminal's resource-planning and control issues related to general terminal operations. Then, the main approach of the study is illustrated in the Section 2.3.

2.2 Resource-Planning and Control Issues in Terminals

2.2.1 The Definition of the Operations Management

All organizations perform the following three functions to create goods and services (Heizer and Render, 2014):

- Marketing: generates demand, takes the order for a product or service;
- *Production/Operations*: creates the product or service; and
- Finance/Accounting: cash control, funds management, etc.

Operations management refers to the *systematic design, direction and control of processes that transform inputs into services and products for both internal and external customers*. A process is *any activity or group of activities that takes one or more inputs, transforms them and provides one or more outputs for its customers*. An operation is *a group of resources that performs all or part of one or more processes* (Krajewski et al., 2009).

Figure 2.1 shows the flow of processes and operations work in an organization. These processes/operations have both inputs and outputs. The inputs can include a combination of *human resources, capital, materials, land* and *energy*. By generating and transforming these inputs, processes and operations provide outputs—i.e., tangible *goods or services*—to both internal and external customers. Customers' feedback and information about performance—i.e., *Quality, Cost, Delivery, Production, Environment, Safety*, and *Morale*—facilitates the organization's ability to manage inputs more effectively and efficiently.

Patrick (2008) notes that a seaport's primary functions include the following:

Administrative functions:

- To control all modes of vehicles that enter and leave the port;
- Environmental control;

- Control of dangerous cargo;
- Safety and security within the port area;
- Immigration, health, customs and commercial document control.

Operational functions:

- Pilotage, tugging and mooring activities;
- Use of berths, shed, etc.;
- Loading, discharging, storage and distribution of cargo.

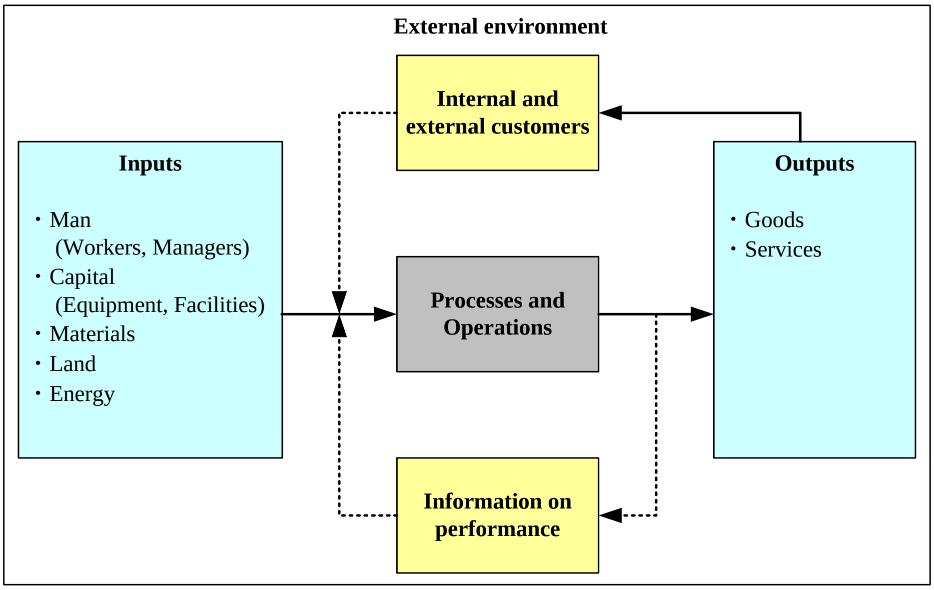


Figure 2.1: General processes and operations work in an organization

The administrative functions are supervised by national and regional port authorities. Improvements to national safety, environmental protection, and the security and convenience of import cargo are generally achieved by making regulations, strengthening inspection and monitoring both the port areas and the cargo. Improvements in ICT systems' processing of Customs Clearance procedures are discussed in Section 4.2.

The terminals' operational functions are embodied as the services of ship mooring and cargo handling. Evaluation of the performance of those functions generally covers both terminal charges and the speed of ship handling. Because of both domestic and foreign competition, the terminal has a pressing need to effectively organize its limit resources (inputs) for improving operational efficiency to enhance their international competitiveness by implementing a speedy service requirement. Seaport terminals consist of both bulk and container terminals, which correspond to the types of goods transported. In this dissertation, the container terminal's operational processes are referred as the study object.

2.2.2 Operations on Container Terminals

Although container terminals differ considerably in size, function, and geometric layout, they principally consist of the same subsystems (Günther and Kim, 2006). These subsystems can be described by the operations processed in the main operation areas, i.e., the *berth*, *quay*, *yard*, and *gate*. The berth and the quay areas are considered *quayside*, whereas the yard and the gate areas are considered *landside*. The *yard*, where containers are stored in stacks, is the intersection of the quayside and landside areas (Carlo et al., 2015). Figure 2.2 shows the main operation areas and the flow of cargo transport.

Generally, containers are loaded and discharged from vessels at quayside, which is the ship berthing and handling area equipped with Quay Cranes (QCs). Import and export containers are stocked in the yard, which is usually divided into various blocks. Special stack areas are reserved for reefer containers or to store hazardous goods. Containers are taken into/out of the terminal by the truck/train that links the terminal to outside transportation systems. Additionally, separate areas are used for empty containers. Some terminals also use sheds either to stuff and strip containers or to provide additional logistical services.

Figure 2.3 shows a schematic view of the facility layout of a container terminal. The name and functions of the main facilities as follows:

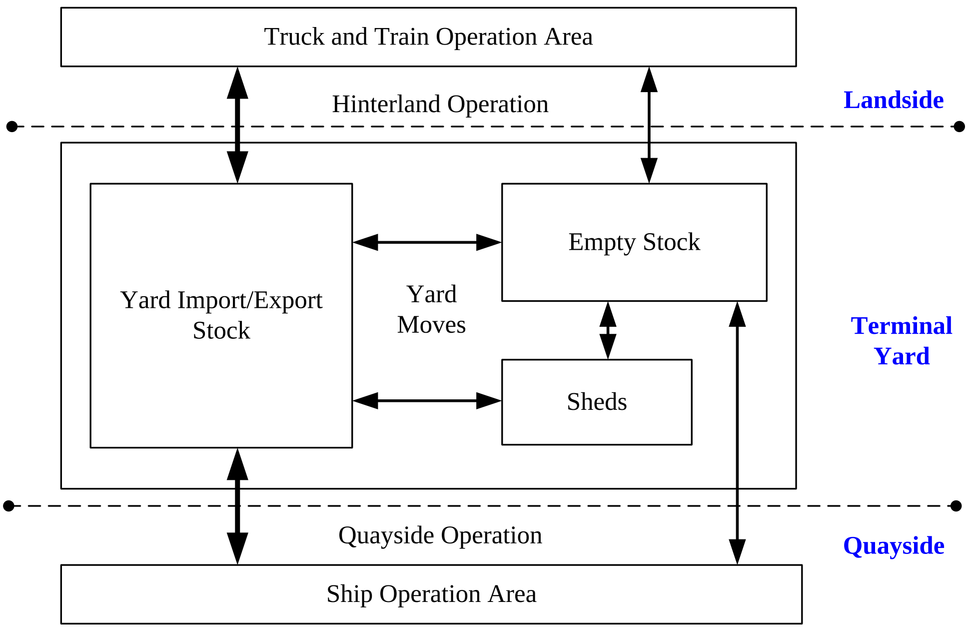


Figure 2.2: Operational areas of a container terminal and flow of transport

(Steenken et al., 2004, author edited)

(a) Berth: a designated location in which a container ship may be moored in the terminal. Determining the number of berths that should be available is a strategic-level decision problem. The length of a berth is typically 250-350 m to moor one or two ships. Recently, berths of 400 m have been constructed for handling larger container ships.

(b) Quay: in recent year, the general water depth of the terminals has changed from -12~-14 m to -15 m~-16 m because of trends in container-ship enlargement.

(c) Apron: the area in which the QCs are located to handle cargo from/to the ship.

(d) Container Yard: the space for stocking most of the containers. The yard is divided into rectangular regions called blocks, which are then divided along their length into 20-foot sections called slots.

(e) Reefer Container Area: the space for stock reefer containers, which need to be connected to electrical plugs for cooling.

(f) Dangerous Cargo Area: the space for stocking dangerous cargos, including tank containers.

(g) Vanpool: the space for stocking empty containers.

(h) Maintenance Area: the space for cargo-handling equipment maintenance.

(i) Terminal Gate: the checkpoint for trucks entering/leaving the terminal.

There are also other facilities in the terminal, including the following: Control Office, Evacuation Tower, Substation, Truck Waiting Area, etc.

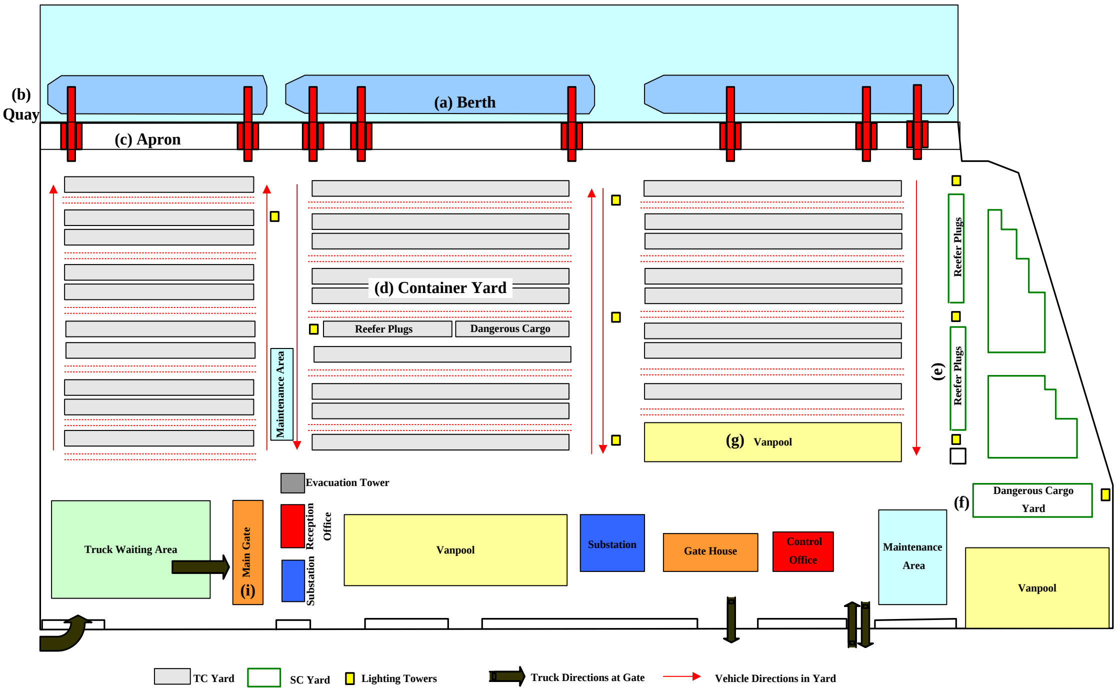
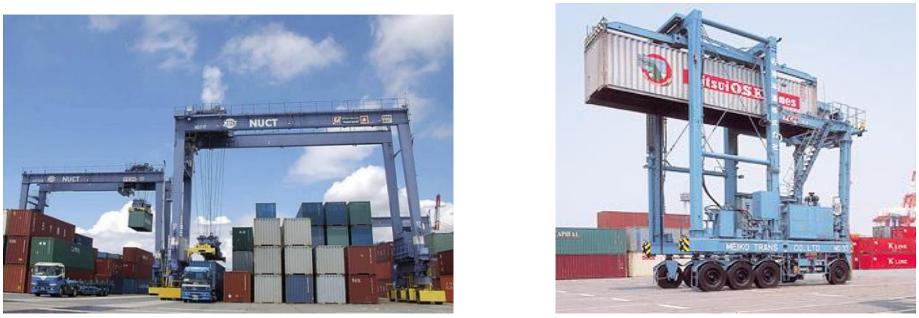


Figure 2.3: The general facility layout of a terminal

2.2.3 Cargo-handling Equipment

The primary cargo-handling equipment used in the container terminal can be divided into quayside cranes, yard cranes, and vehicles. Different terminals usually employed handling equipment of different types and different automaticity that have been considered in terms of their scale, cost, throughput, and other factors that influence terminal. The most common types of cargo-handling equipment employed in the container terminal are shown in Figure 2.4.

(1) Quayside Cranes: A single lift-gantry crane (left) and a twin-lift spreader (right)



(2) Yard Cranes: A transfer crane (left) and a straddle carrier (right)

(3) Vehicles: Trailers

Figure 2.4: Most common types of cargo-handling equipment employed in the terminal

(Figure (1), (2) Source: Nagoya Port Terminal Pubic Corporation)

(1) Quayside Cranes

Quayside Cranes (QCs), also called ship-to-shore cranes, are large, typically rail-mounted, non-automated gantry cranes located on shore to discharge/load vessels with a discharging/loading plan in ship operations. Each QC is equipped with trolleys that can move along the crane’s arm to transport the containers from ship to vehicle and vice versa. The containers are picked using a spreader, which is a pickup device attached to the trolley (Carlo et al., 2015). With the recent increase in large-scale container ships, multi-lift spreaders, which can pick up multiple containers at one time, and double-trolley QCs, which are designed to reduce the trolleys’ horizontal driving distance, are set up in some terminals to reduce the cycle time and improve the handling efficiency of ship operations (Steenken et al., 2004; Kim, 2008; Bae et al., 2011). In this dissertation, the QC is assumed as the single lift Gantry Crane (GC).

(2) Yard Cranes

In yard operations, cargo-handling equipment is used both to stack the containers and to transfer containers to and from transport vehicles. The most common types of equipment are straddle carriers (SCs) and yard cranes (YCs), primarily including rail-mounted gantry (RMG) and rubber-tired gantry (RTG) cranes.

RMGs are fully electrified cranes that are operated by railway and are suited for fully automated cargo handling and stocking large numbers of containers. RTGs are operated by onboard drivers and are more flexible in operation because RMGs can only move on rails. RMGs are usually used in large-scale, stable terminals in which containers can be stacked in high tiers. In this dissertation, the yard crane is assumed to be the RTG, which is called the transfer crane (TC).

SCs are characterized as a mixture of a vehicle transporter and a transfer crane, and they are employed both to transport containers in the yard to/from the quayside and to store those containers in the stack. Because of SC systems’ operational flexibility, many average-size or low-volume container terminals in Europe commonly use them (Ballis et al., 1997; Sgouridis and Angelides, 2002; Luo, 2013).

Furthermore, some other types of handling equipment are used in terminals. Top lifters, forklifts and reach stackers are used to move and stack light or empty containers in the vanpool or other types of intermodal transportation.

(3) Vehicles

Vehicles, also called horizontal transport in the terminal, are used to transfer the containers from the quayside to various stacking locations in the yard area and from the stacking locations to the terminal outside. To easily distinguish between vehicles belonging to the terminal (inside) and vehicles belonging to the customer (outside), the outside vehicles are denoted as trucks.

Depending on whether it automatically drives itself or needs a driver, vehicles can be divided into automatic guided vehicles (AGVs) and trailers/multi-trailers. AGVs are robotics able to drive on a road network that consists of electric wires or transponders in the ground to control the position of the AGV, and they can load either one 40/45F container or two 20F containers (Steenken et al., 2004). Trailers are the traditional vehicle used for container transfer in container terminals. Multi-trailers allow transportation of a large number of containers. In addition, automated lifting vehicle (ALV) is characterized as a mixture of a vehicle transporter and an YC.

(4) The Character and Comparison of Cargo-handling Systems

Because each terminal has unique operational and stacking characteristics, terminals adopt various types of cargo-handling systems. The features of the most common cargo-handling systems are summarized in Table 2.1. The chassis system is a wheeled structure designed to carry containers for the purpose of truck movement between storage-yard and shipping facilities. This system has high flexibility but low storage capacity for the increased amount of land needed to store chassis and containers. As mentioned above, SCs are characterized as a mixture of a vehicle transporter and a transfer crane. Therefore, the straddle carrier system's flexibility is operational in nature. However, containers cannot be stacked higher than four tiers, and the driver is much less safe than in other systems as a result of the SCs' limitations. The yard-crane system combines the yard crane for handing and trailers for transportation. This system has less flexibility and a comparatively high initial cost. However, its storage capacity, maintenance cost and driver safety is considered better than other systems.

Table 2.1: Features of the main cargo-handling systems

System Features		Chassis System	Straddle Carrier System	Yard Crane System
Financial Cost	Equipment Cost	Medium	Low	High
	Equipment Maintenance Cost	Low	High	Low
	Terminal Development Cost	Very low	Medium	RTG: Medium RMG: High
	Number of Operational Crew Required and Skill	High Low skill required	Low High skill required	Low Medium High skill required
Operation Convenience	Re-handling Rate	None	Medium	High
	Storage Capacity	Low	Medium	High
	Operating Flexibility	High	High	RTG: Medium RMG: Low
	Container Damage Incidence	Low	High	Low
	Mechanical Failure Rate	Low	High	Low
Welfare	Safety	Medium	Low	High
	Noise	Medium	High	Low
	Crew Tiredness	Medium	High	Low

(Source: Amada, 2001; Alderton, 2008; Nishimura, 2009; author edited)

2.2.4 Container Terminal Performance Measurement

Performance measurement is an essential element both in decision making and in effective planning and control. Terminals are simultaneously confronted by various stakeholders' restrictions and demands: staff members require high levels of welfare; authorities require legal compliance; and trucks and ships require short processing and flexible service times via a low charge rate. Therefore, various types of indicators are used to measure terminal performance; those indicators can be summarized as service-level indicators, terminal-efficiency indicators, equipment-efficiency indicators and cost-efficiency indicators (Kemme, 2013). Service-level indicators principally include ships and trucks' turnaround time and the terminal's handling and storage charges. Terminal-efficiency indicators are generally used to evaluate transshipment and storage functions. Equipment-efficiency indicators generally include the utilization and productivity of the cargo-handling equipment. Cost-efficiency indicators evaluate a terminal's cost situation, especially its average cost for handling a container, which affects customers' choice of terminal.

Ship turnaround time in the terminal includes time to wait, to berth and to be handled. From the vessel operators' perspective, it is only a vessel's travel time that is economically productive: reductions in ship turnaround times could increase the propitiation of travel time and boost revenue from additionally transported containers (Meisel, 2009). Consequently, the terminal can handle more ships. Therefore, ship turnaround time is regarded as the terminal's most important service-level indicator.

Gross crane rate (GCR) is defined as the average number of containers handled per QC working hour. GCR is considered one of the most important equipment-efficiency indicators that affect ship turnaround time. Meanwhile, GCR is either directly or indirectly affected by efficiency changes in other handling equipment (YCs or trailers) (Kemme, 2013).

In this dissertation, the ship handling time as well as the number of containers handled in a defined period are considered the main performance indicators.

2.2.5 Classification of Terminal Planning and Control Issues

To efficiently generate and utilize resources and to improve operations, the decision-making problems related to seaport terminals' logistics-planning and control issues can be assigned to three categories: *Terminal Design* (strategy level); *Operative Planning* (tactical level); *and Real-time Control* (operational level) (Günther and Kim, 2006). The figure, which has been edited by the author, is shown in Figure 2.5.

Terminal design problems are usually solved by facility planners in the initial planning period for port reform or new port construction, which is applied to study and compare various types of terminal layout and handling-equipment selection (type and number) while considering both economic and technical performance. Additionally, the design and construction of ICT support systems is a very important issue at the strategy level.

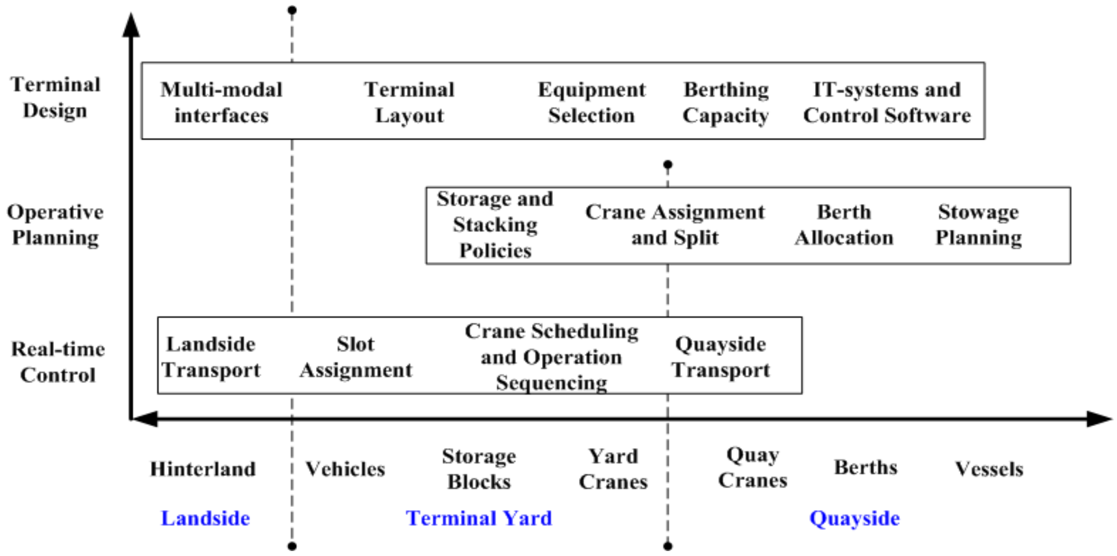


Figure 2.5: Logistics planning and control issues in seaport terminals

An operative-planning problem involves both guidelines and basic planning procedures for performing a terminal's various logistics processes. The terminal is usually studied by subdivided into various modules related to its various types of resources. The real-time control problem is the difficulty in making decisions as a result of the short time limit during the real operation (Günther and Kim, 2006). By combining the operative and real-time levels into the operational planning level, the problem can be categorized into the terminal design and the operational planning problem (Kemme, 2013). The problem primarily includes the scheduling and allocation of the cranes and berths, stowage planning in both the ship and the yard, dispatching and routing vehicles.

Since the late 1990s, OR (operations research) models and methodologies have been widely used to solve terminal-planning problem (Vis and de Koster, 2003; Steenken et al., 2004; Kemme, 2013). However, to obtain a better understanding of all of a terminal's processes and decisions, the simulation method can be used to evaluate control concepts, layouts and cargo-handling equipment. Furthermore, it is possible to solve a problem that arises simultaneously at several levels, and results can be obtained by integrating different handling systems through the use of simulation (Vis and de Koster, 2003).

Moreover, the terminal's design and planning problems relate to operations in the landside, terminal yard, and quayside. This dissertation studies the system of ship handling processes using the vehicle-dispatching problem in the terminal yard and quayside. Furthermore, the method of discrete-event simulation is adopted.

2.3 Simulation

2.3.1 Simulation Modeling

Simulation is the process of designing and creating a computerized model for a real or proposed system for the purpose of conducting numerical experiments to give us a better understanding of the behavior of that system for given set of conditions (Kelton et al., 2004).

Although there are various types of simulation models, the focus of this dissertation is *discrete-event* simulation, which is characterized as discrete, dynamic, and stochastic. When such an approach has been adopted, the flow of *entities* that move through the system must be modeled. From the perspective of a container terminal, ships and containers are the primary entity. Entities have various characteristics—i.e., *attributes* such as container types and ship loads. The entities flow through the system while using a series of *resources*, such as berths, GCs, YCs, and vehicles. Therefore, a simulation model is a computer program that represents the system's logic: i.e., entities arrive with various attributes and wait for resources; next, they are processed by resources; and finally, those resources release the entity. Moreover, this program tracks *performance measures* such as ship handling time, berth throughput, trailer turnaround time and other useful statistics. Because real-world simulation models are relatively large, and because the amount of data stored and manipulated is so vast, the models' runs are usually conducted with the help of a computer.

Figure 2.6 is a schematic of simulation study. The iterative nature of the process is indicated by the system under study and the cycle repeats. In a simulation study, human decision making is required at all stages, namely, model development, experiment design, output analysis, conclusion formulation, and making decisions to alter the system. Conversely, the simulation model-running stage can be efficiently performed by simulation software packages. The steps involved in developing a simulation model, designing a simulation experiment, and performing simulation analysis are as follows (Maria, 1997; Wijewickrama, 2006; Zhao, 2013):

[Step 1] Problem formulation

The analysis begins when information about the problem is gathered. In a seaport terminal system, this information may include ship handling time, cargo-handling equipment utilization, trailer waiting time, etc.

[Step 2] Establishing objectives and an overall project plan

The proposal for the study is prepared in this step. The objectives indicate the questions that are to be answered by the simulation study. The project plan should indicate the required time, cost, resources, investigation, and output at each stage. The study's overall objective is defined and performance measures are identified.

[Step 3] Model building

The real-world system is modeled, considering not only the mathematical and logical relationships but also the structure of the system. In a container-terminal model, the basic model of ship, containers, and resources (GCs, yard block, trailers, TCs) is constructed. Next, the node, route, and connections are set to connect the positions.

[Step 4] Data collection

After identifying the process, the analyst collects data indicating the processing time for containers, information for yard block divisions, etc. In this step, the analyst collects real-time data. The data collection involves input variables (arriving time, processing time, travel time between yard blocks, block inventory capacity), the performance of the existing system (throughput, cycle time), and entities of the randomness in the system (the percentage of each container type and size). Data collection and model building proceed simultaneously, because the analyst can build the model while collecting data. Collecting and evaluating input data is very time consuming; in a real-world simulation study, as the complexity of the model changes, the required data may also change.

[Step 5] Coding

This step translates the conceptual model developed in step 3 into a computer-recognizable problem. Using sophisticated software, the analyst can make choices according to the model's requirement. In this dissertation, the object-oriented simulation software *Simio* is used for coding.

Simio is a simulation-modeling framework based on graphical object-oriented programming. The model is realized using multiple modeling paradigms, including event, process, object, system-dynamics and agent modeling views (Thiesing and Pegden, 2014).

[Step 6] Verification

After developing the model, the analyst must check whether it works correctly. Throughout the verification process, the analyst attempts to find and remove errors in the model's logic. For example, using Simio's trace facility, the analyst can find and remove unintentional errors in the model's logic.

[Step 7] Validation

This step determines whether the conceptual model is an accurate representation of the real system. For this purpose, the analyst compares the model's performance with the real system's performance. In this dissertation, the average GC handling rate of the model system is checked to determine whether the parameters obtained from the system correspond with the parameters of the real-world system. Furthermore, the test is validated to determine whether the original simulation model behaves the same as the real system. In such a case, the statistical significance should measure within the confidence interval.

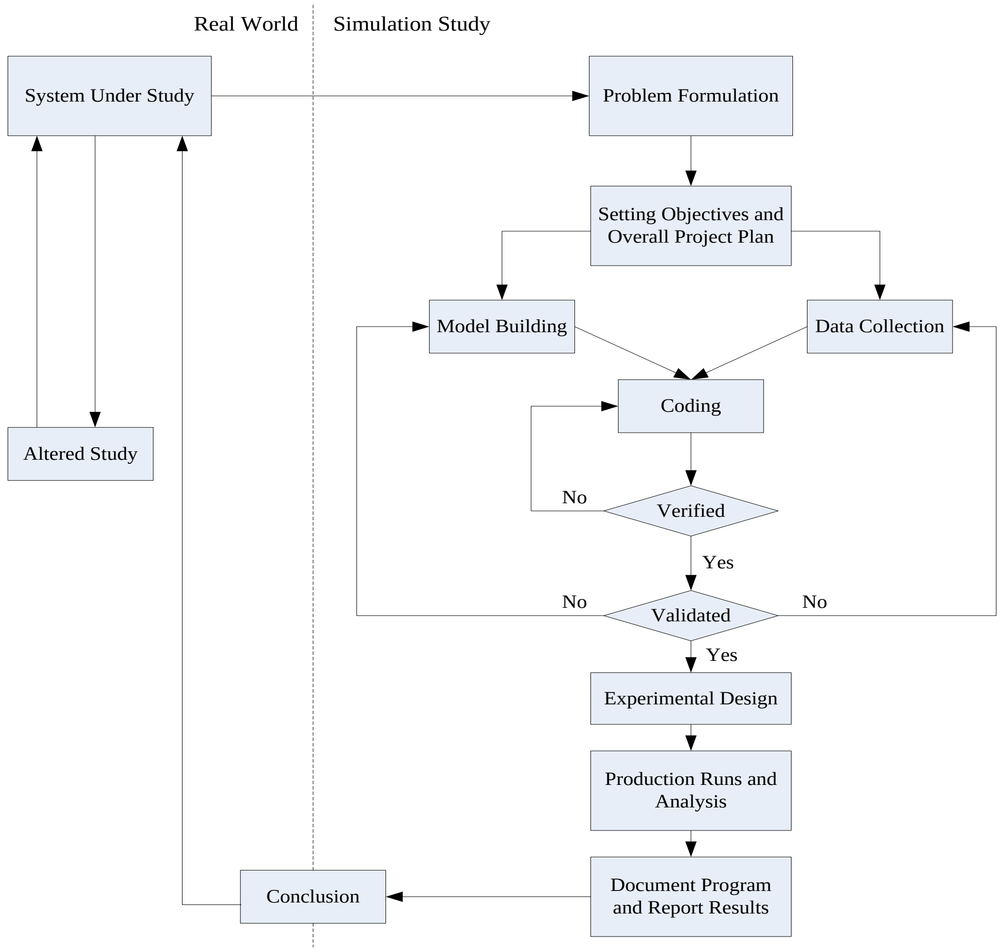


Figure 2.6: Simulation study schematic

(Source: Maria, 1997; Wijewickrama, 2006; Zhao, 2013)

[Step 8] Experimental design

In this step, analysts work with issues such as how long to run the model (sample size or number of replications), manner of initialization (terminating simulation system or steady-state simulation system), and which statistical tests are valid for the data. In this dissertation, the container-terminal system is developed as a steady-state simulation system with a warming running time.

[Step 9] Production runs and analysis

This step involves running the models and performing analyses of the performance metrics. Usually, simulation models are used to compare a large number of alternatives and select a few recommended alternatives for further analysis. To shorten ship-berthing time, several scenarios are performed for comparison.

[Step 10] Document the program and report results

Documentation is necessary for future modifications of the model. The results of all of the analyses should be reported to review alternatives, criteria and formulations.

The simulation cannot use a deterministic single value when inputs vary (e.g., ship arrival) and service times are uncertain (e.g., processing time of various types of handling equipment). It is enormously complex to model the cargo-handling processes of the container terminal because of variability that results from changing ship arrivals, varying shiploads and equipment numbers.

2.3.2 Simulation on the Seaport Terminal

Given the terminal's randomness and complexity, simulations have been widely using in solving its problems. Corresponding to the levels of division given to the logistics-planning and control issues set forth in Section 2.2.5 and Figure 2.5, there are three types of simulation on the terminal that can be distinguished: strategic, operational, and tactical simulation (Steenken et al., 2004):

Strategic simulation is usually used on the terminal design period, which is applied to study and compare different types of terminal layout and handling equipment with respect to expected efficiency and costs. The experiment can be conducted using various scenarios with different layout and equipment-employment strategies, which are compared to performance and cost indicators. Simulation systems allow either the design of realistic scenarios the importation of existing terminals' data to match reality.

Operational simulation is applied to test various types of terminal logistics and optimization methods. Because it would be prohibitively costly and difficult to perform the experiment with an actual terminal, improvement and optimization methods are tested in a simulation environment before they are implemented in the real terminal.

That said, tactical simulation means integrating the simulation system into the terminal's operation system. Tactical simulation is seldom or only partially installed at the terminal because the real operational data must be imported and analyzed in a manner that synchronizes with the operation.

The literature review of simulations on seaport terminal operations is contained in the next chapter.

3 LITERATURE REVIEW

3.1 Introduction

In recent years, because of containerization's advantages of low costs, reduced packaging, convenience and efficient handling, the international containerization market has been experiencing high growth in tandem with increased international trade (Yang and Takakuwa, 2015). Accordingly, an increasing number of container shipments have induced higher demands for maritime container terminals, container logistics and management and technical equipment (Steenken et al., 2004).

Container terminals are required to handle a changeable quantity of containers with limited resources such as berths, stockyards, and cargo-handling equipment. That notwithstanding, the container terminal represents a complex system with highly dynamic interactions among the various handling, transportation, and storage units, incomplete logistics planning and incomplete knowledge about future events (Günther and Kim, 2006). Therefore, the management and control of information about cargo, cargo-handling equipment and other terminal resources remains a difficult problem.

Given the terminal's randomness and complexity, *simulation technology* is considered an effective research tool. Many recent studies have used simulation technology to study the container terminal, especially the scheduling, routing, and dispatching problem of container-handling equipment and the stockyard problem.

Information and communication technology (ICT) systems are widely used to assist and support seaport terminals' operations (Liu and Takakuwa, 2011). A terminal operating system is a software application that supports a container terminal's planning, scheduling and equipment-control activities (Boer and Saanen, 2008). Terminal operating systems often utilize ICTs such as the Internet, EDI processing, wireless LANs, radio-frequency identification (RFID), etc., to efficiently control the movement and storage of both cargo and support.

This chapter reviews the literature, focusing on the following two topics. First, the literature related to terminal planning and control issues is discussed, particularly with respect to terminal design, cargo-handling equipment scheduling and allocation and primarily using simulation techniques and methodologies. Second, the literature concerning the application of ICT on both container-terminal and other logistics systems for operational analysis is discussed. These two research areas comprise the literature reviewed in the following sections.

3.2 Literature Review on Terminal Planning and Control Issues

3.2.1 Terminal Design

Container terminals are continuously challenged to increase their throughput capacity, giving way to many innovations in terms of container design, material handling equipment, and operations research applications (Carlo et al., 2015).

Liu et al. (2002) have designed four types of automated container terminals with different cargo handling equipment: AGVs, linear motor conveyance systems, overhead-grid rail systems, and high-rise automated storage and retrieval structures (AS/RS). Those authors have developed both a simulation model and a cost model to analyze and evaluate each terminal system performance under the same operational conditions. By conducting an experiment that compares the scenarios' system performance and cost efficiency, their results indicate that automation could improve terminal performance at a considerably lower cost.

Petering (2009) has evaluated the effects of block widths ranging from two to fifteen rows on terminal performance via a discrete simulation model of a transshipment terminal. The results show that the utilization rate of QC was concave to block width when the yard block capacity and the amount of other cargo-handling equipment were constant.

Petering and Murty (2009) have developed a simulation model to study the influence on average QC rate by the length of the block and the YC dispatching strategy among the blocks in the same operational zone. They have found that the restrictive YC deployment rule resulted in a higher rate of quay-crane work than did the free transfer rule.

Longo (2010) has proposed a research approach for designing operational policies and practices to manage container flows toward the inspection areas. That author has constructed a simulation model in which the level of the input parameter values can be varied easily through the user interface.

Taner et al. (2014) have compared four types of the common layout of the artificial container terminals that are built artificially near coastlines. The transporters' dispatching rules and resource-allocation strategies in terms of total annual handling amount was examined using a simulation model. The result showed that layout format in artificial container terminals has a significant effect on terminal operations performance.

3.2.2 Cargo-handling Equipment Scheduling and Allocation Problem

To address the problem of cargo-handling equipment scheduling and allocation, both the OR method and mathematical modeling are widely adopted by scholars to solve the problem of optimizing the subhandling system (Vis and de Koster, 2003; and Steenken et al., 2004; Stahlbock and Voß, 2008). This section primarily reviews studies that use the simulation technique.

At the quay side, Legato et al. (2008) have developed two OR models to study the GC scheduling problem in a SC system and to minimize the ship's overall completion time. A queuing network and an integer-programming model have been used for supporting allocation-scheduling decisions.

Clausen and Kaffka (2012) have developed a GC handling task-sequencing strategy with a priority number for a multi-GC model in a container terminal. A process of setting priority numbers has proposed, considering loaded cut-off time, waiting time, travelling time of the task, and the criteria of exclusion. The cut-off time has been given the highest weight in the study because the main objective is to shorten ship dwelling time.

For the yard operation, Guo et al. (2008) have used mathematical modeling and simulation to study the YC dispatching problem to minimize average vehicle waiting time. By making use of the real time predicted vehicle arrival information, the situation is executed such that YC will start moving towards a next job location before the designated vehicle will be considered to arrive there. The YC dispatching algorithm that is based on real time data driven simulation to generate optimal dispatching sequences for each planning window has been proposed.

Petering et al. (2009) have investigated a pure transshipment terminal to determine how a container terminal's long-run average QC rate depends on the real-time system of automatically dispatching YCs for container-handling tasks in the yard. Based on a discrete event-simulation model, their results indicated the following: (1) YC should prioritize the retrieval work over storage of containers in stacks; and (2) The YC dispatching system should consider not only trucks that are waiting for service but also trucks that are heading toward the yard.

Huang et al. (2012) have presented two optimal algorithms to find the optimal YC job sequence for serving a fleet of vehicles for delivery and pickup jobs that have scheduled deadlines and predicted vehicle-arrival times. The objective was set to minimize the total tardiness of incoming vehicle jobs.

Vehicles are used to transfer containers among the yard, the quay/yard/yard and the outside. AGV or trailers/trucks are commonly used as terminal vehicles.

Yang et al. (2004) have presented both a simulation model and a procedure that govern the transport vehicles of automated container terminals. The vehicle travel speed with constraints on the productivity has been analyzed. They have found that the ALV is superior to the AGV in productivity due to the AGV spending more time in waiting YC.

Bish et al. (2005) have demonstrated that the greedy algorithm (i.e., giving the job to the first available vehicle) is the near-optimal method for a single-crane model; for a single ship with multiple cranes, the greedy algorithm does not perform optimally, although performance is reasonably effective.

Cheng et al. (2005) have proposed a network flow model to solve the AGV dispatching problem and specifically, to minimize the total AGV waiting time.

Briskorn et al. (2006) have presented an inventory-based consideration to assign the AGV to the GC that has a relatively small number of AGVs currently assigned.

Lee et al. (2007) have studied the influence of both different designs of vehicle types and layout of the storage yard on the system efficiency. Four types of simulation model have been constructed to perform experiment. GCR has been used as the performance measure in the study.

3.2.3 Overall Terminal Modeling and Simulation Optimization

This subsection focuses on reviewing the literature on the overall terminal model. Simulation is used as an intelligent tool not only to solve problems that arise simultaneously at several levels but also to investigate and evaluate the results obtained from integrating different sub-handling system (Vis and de Koster, 2003)

Nevins et al. (1998) have described a discrete-event simulation model written in a time-stepped, object-oriented program that addresses seaport operations in the context of military mobility. Determination of the seaport’s throughput capability was assumed to be the overall goal of their study.

Yun and Choi (1999) have proposed a simulation model for container-terminal-system analysis. The simulation model is developed using the object-oriented simulation software SIMPLE++. The model consists of the gate, the container yard, the berth, and the facilities (i.e., YCs, GCs, and trailers). The performance of the simple container terminal, which is a reduced system of a real terminal in Pusan, Korea, is analyzed.

Sgouridis and Angelides (2002) have modeled an "All-Straddle-Carrier" system that focuses on handling import containers that have been transported on trucks. Import area of a medium-size Europe terminal has been modeled and analyzed under the several different degrees of the traffic loads to optimize SC number.

Murty et al. (2005) have developed a decision support system for making daily operational decisions in a container terminal in Hong Kong. Several methods of decisions making have been studied to minimize the vessel berthing time, the resources needed for handling the workload (number of containers need to be processed during the defined period), the waiting time of trucks, and the congestion on the roads inside the terminal, and to make the best use of the storage space.

Bielli et al. (2006) have presented the components architecture of the object-oriented model that simulated container terminal. A simulator has been constructed using UML diagrams, and the code is written in JAVA. The number of containers handled by QC during four shifts has been used for validation in their study.

Bae et al. (2011) have compared the operational productivities of the AGVs and ALVs when used in combination with the QCs of various performances by performing a simulation experiment; they have constructed a simulation model of the traffic-control scheme both to find a minimum time route and to avoid deadlock. Four types of QCs with various levels of productivity were given as the various conditions of the scenarios.

3.3 Literature Review of ICT System Application

This section reviews studies of ICT application in both seaport terminals and other fields in terms of logistics and supply management for operational analysis.

Kia et al. (2000) have investigated the importance and the cost of ICT and its role in improving in cargo-handling operational system. A simulation model is developed in the study to compare the performance between the systems equipped with and without electronic devices. Experimental results have demonstrated that SC waiting time could be reduced by electronic devices supporting significantly due to the elimination of search time for the right yard slots.

Lee et al. (2000) have summarized the important factors to be considered in designing Electronic data interchange (EDI) system of the container cargo logistics. The factors comprised the framework design, inclusion of Customs in the system design, sharing system of cargo data, and global message standard.

Boer and Saanen (2008) have presented an approach to test and tweak the TOS and train operators on a virtual terminal. They have introduced an emulation tool that allows the users to experiment with a virtual environment and real TOS.

Hsu et al. (2009) have constructed a network to analyze cargo, information and human flows in the import cargo process in an international air cargo terminal for evaluating the performance of applying RFID. They have found RFID application on the Customs Clearance could drastically improve the efficiency of cargo handling, and save the inventory cost of shippers and labor cost of operators.

He et al. (2010) have employed the simulation approach to quantify the benefits of RFID deployment of air cargo at the airport. Their results have indicated that RFID system is appropriate for the time-sensitive industrial and commercial practices.

Additionally, Liu and Takakuwa (2011) have proposed a simulation approach for collecting the required data from real-time tracking data from ICT system to model an entire operations process at a container terminal. GPS has been used to collect real-time tracking data for the simulation of an open-pit copper mine both to determine the optimized number of trucks and to estimate the maximum mining capacity (Tan et al., 2012). Shahandashti et al. (2010) have used GPS and RFID technology-captured data to assess productivity in construction.

4 THE APPLICATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON SEAPORT TERMINALS

4.1 Introduction

The term "*Information and Communication Technology* (ICT)" is used to delineate the various telecommunications and information technologies that have been used in the field of transport since the mid-1980s (Giannopoulos, 2004). With reduced hardware costs and rapid capability development, ICT systems are increasingly used to support operations management in freight transport via international logistics, international supply chains, and seaport terminals. The most commonly adopted technologies include the Internet (local area network and wide area network, i.e., LAN and WAN); electronic data interchange (EDI), which is the computer-to-computer exchange of structured business documents in a electronic format based on an international standard; and the global positioning system (GPS), which is a space-based satellite navigation system that provides location and time information, whereas differential GPS (DGPS) is an enhancement to GPS that provides improved location accuracy. Electronic seals and electronic tags (dimensional code and radio frequency identification, i.e., RFID, which is the electricity tag attached to objects that can automatically identify and track) are used to construct and realize the systems' assistance and support functions. Additionally, recent developments in field of ICT such as cloud computing, social networking and wireless communication have further revolutionized both information sharing and system integration (Garstone, 1995; Kia et al., 2000; Lee et al., 2000; Ueno, 2000; Giannopoulos, 2004; Angeles, 2005; Gil et al., 2011; Eliza et al., 2013; Harris et al., 2015).

The main purpose of using ICT systems for maritime operations management is to give management a total picture of what is happening as it happens, which at one time could not be properly completed because of the systems' vast complexity. ICT systems are often found in ports for the following reasons (Alderton, 2008):

(1) Management of vessel operation; control over vessel arrival/departure and attendant facilities such as tugs, berths, pilots, etc.; and

(2) Management of cargo and terminals:

- To centralize the management of cargo information and data;
- To optimize the flow and control of cargo through the terminal;
- To provide data and statistics;
- To produce necessary documents;
- To simplify reporting procedures to various agencies;
- To calculate charges and issue invoices;
- To help organize labor, and
- To assist management in quality and environmental control.

Many other types of ICT systems, such as the systems that support shipping navigation and sea-area security, are also employed in maritime transport (Giompapa et al., 2009; Pietrzykowski et al., 2012). Two types of systems—the electronic customs-clearance system and the terminal operating system—are discussed in this chapter.

To control and manage a seaport terminal's operation processes and facilitate international trade, there are two primary types of ICT systems used in the seaport terminal via international logistics: (1) the electronic customs-clearance system, which is used to manage legal documents; and (2) the terminal operating system, which is used to manage cargo-handling operations.

This chapter aims to clarify the application of ICT in customs clearance and terminal operational control. To clarify the systems, this study presents the example of ICT systems in Japan. In Section 4.2, the customs-clearance procedure and the how the system manages these procedures is studied, with the integrated method of the "Single-Window System" indicated to be effective in shortening the lead time for document processing related to import cargos. In Section 4.3, after a brief description of the material handling flow of the international trade cargo in both the terminal and the free-trade zones, a terminal operating system is investigated, and both the system-control processes and the details of the system-tracking data are presented. Consequently, this chapter is also studied to enable the achievement of *Objective One*.

4.2 Electronic Customs Clearance System

4.2.1 Customs Clearance in the International Trade

In the international trade transactions, in order to prevent the risks caused by the spatial and temporal separation, a very large number of documents used for certificate and instructions via trade cargo information are involved. These documents are partially required by the exporting country, importing country, banks involved, shipping (transportation) company, and the importer of the goods (Pierre, 2013). As an international standard electronic format, EDI realized the necessary documents via information exchangeable and manageable with the standard among the key stakeholders in the international trade transactions.

The main players in the international trade and logistics include Customs, which is the governmental authority responsible for collecting customs duties and controlling the flow of goods (including animals, transportation, personal effects, and hazardous items) into and out of a country. Therefore, the national customs authority grants to both imported and exported cargo the documented permission to pass (so that imported cargo can enter the country and exported cargo can leave the country). Meanwhile, depending on the type or characteristics of the object of a customs declaration, other government agencies also have responsibilities during the customs-clearance processes.

The activities and documents required by the national authorities are assumed to vary by country. In this dissertation, the case of the customs-clearance processes and the application of the ICT system to Japan's seaport are discussed.

As a national transport infrastructure and the primary transport link in international logistics, seaports are the location of a variety of activities, including maritime transport, shipping, and marine services. In addition to seaports' management bodies, an interlocking network of administrative organizations manages port-related social and economic activities (MLIT, 2006). Since 1991, Japan has developed an ICT system to support sea-cargo customs-declaration procedures; that system is called the Nippon Automated Cargo and Consolidated System (NACCS). However, several systems built separately by other agencies, which engage in little information sharing.

When an ocean-going ship arrives at the port, the activities that are the responsibility of the government officials whose jobs relate to port use are shown in Table 4.1. Additionally, the table lists the related ICT systems and their year that they entered operation supervised by various government agencies.

Identical items were required to be filled in and similar documents were required to be submitted because the different systems were controlled by different agencies. As a result, the average lead-time for import cargo in Japanese ports was three times longer than in the port of Singapore and two times longer than in the port in Korea (Ono, 2006). Therefore, there was a pressing need to facilitate international trade by integrating customs-clearance systems and simplifying submission procedures.

4.2.2 Single-Window System

The efficiency of ICT depends on close alignment and integration between the functions and services performed by the customs administration and the information systems relied upon to fulfill the administration's responsibilities (Wulf, 2005). The concept of a "single-window" that is defined and promoted in the UNECE's brochure is described as follows: "A facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfill all import, export, and transit-related regulatory requirements. If information is electronic then individual data elements should only be submitted once."

Table 4.1: Government officials' related activities and ICT system with port use

Object	Related Activity	Related System	Responsible government agency	Minisitry
Port	Navigation safety and systematic maintenance within port facilities	**Port EDI** (From 1991)	Poster master (Coast Guard)	Ministry of Land, Infrastructure and Transport (MLIT)
Ship	Regulation of port transportation, supervision (sales registration, fee forwarding, etc.)		District Transport Bureau	
	Supervision of coastal warehouse industry			
	Supervision of maritime service industry			
	Regulation of duties, tonnage taxes, special tonnage taxes, other assessments, levies, and bonded areas	**Sea-NACCS** (From 1991)	Customs	Ministry of Finance (MOF)
Cargo	Approval of imported and exported freight	Japan Electronic open network TRAde control System **(JETRAS)** (From 2000)	Regional Bureau of Trade and Industry	Ministry of Economy, Trade and Industry (METI)
	Inspection and quarantine of imported and exported animals	Animal Quarantine Inspection Procedure Automated System **(ANIPAS)** (From 1997)	Animal Quarantine Office	Ministry of Agriculture, Forestry, and Fisheries (MAFF)
	Inspection and quarantine of imported and exported plants	Plant Quarantine NETWORK **(PQ-NETWORK)** (From 1997)	Plant Quarantine Office	
	Inspection and quarantine of imported and exported food	Food Automated Import Notificatgion and Inspection System **(FAINS)** (From 1996)	Quarantine Office	Ministry of Health, Labor and Welfare (MHLW)
People	Port quarantine of seamen and passengers	**Port EDI**		
	Control of immigration and emigration	**Crew Landing Support System** (From 2008)	Immigration Office	Ministry of Jusitice (MOJ)

(Source: MLIT, 2006; UNTIED, 2007; Author Edited)

Because Customs is the leading agency behind electronic customs-clearance systems in Japan, the NACCS and others have computerized the trade-related administrative procedure system into a comprehensive computer interface system which that enable the submission of all trade-related documents—i.e., lodge import/export declarations, vessel-clearance transactions, and certain quarantine and immigration procedures—with a single transmission (Japan Customs, 2015). The customs-clearance process for cargo in port terminals includes complicated procedures and involves many relevant operational units. The NACCS marine-cargo processes and procedures are shown in Figure 4.1.

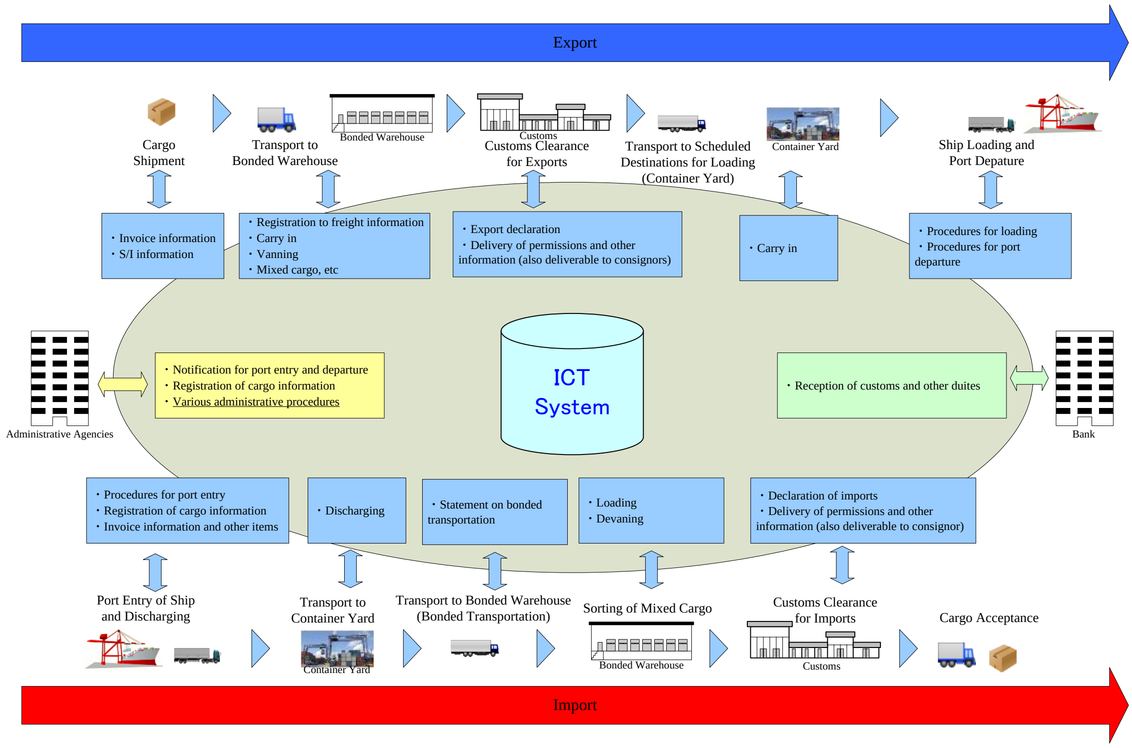


Figure 4.1: International marine-cargo procedures with ICT systems

(Source: NACCS; Author edited)

The establishment of the single-window system was planned for 2003 (UNECE, 2007). The system is designed to include standardized user-identification codes, terminal screen layouts and methods of data entry. In 2003, NACCS, Port EDI and the Crew Landing Support System were connected. Users can submit documents through either NACCS or Port EDI, and data are then duplicated and sent to the other systems. In October 2008 and February 2010, Port EDI and JETRAS were sequentially merged into NACCS. The new single window, called the Common Portal, has been in operation since 2008. In October 2013, other systems (including FAINS, PQ-Network, and ANIPAS) were integrated into NACCS, which became the one-stop service for Customs declarations. Therefore, the single-window development process of NACCS system integration can be divided into four phases, which are shown in Figure 4.2.

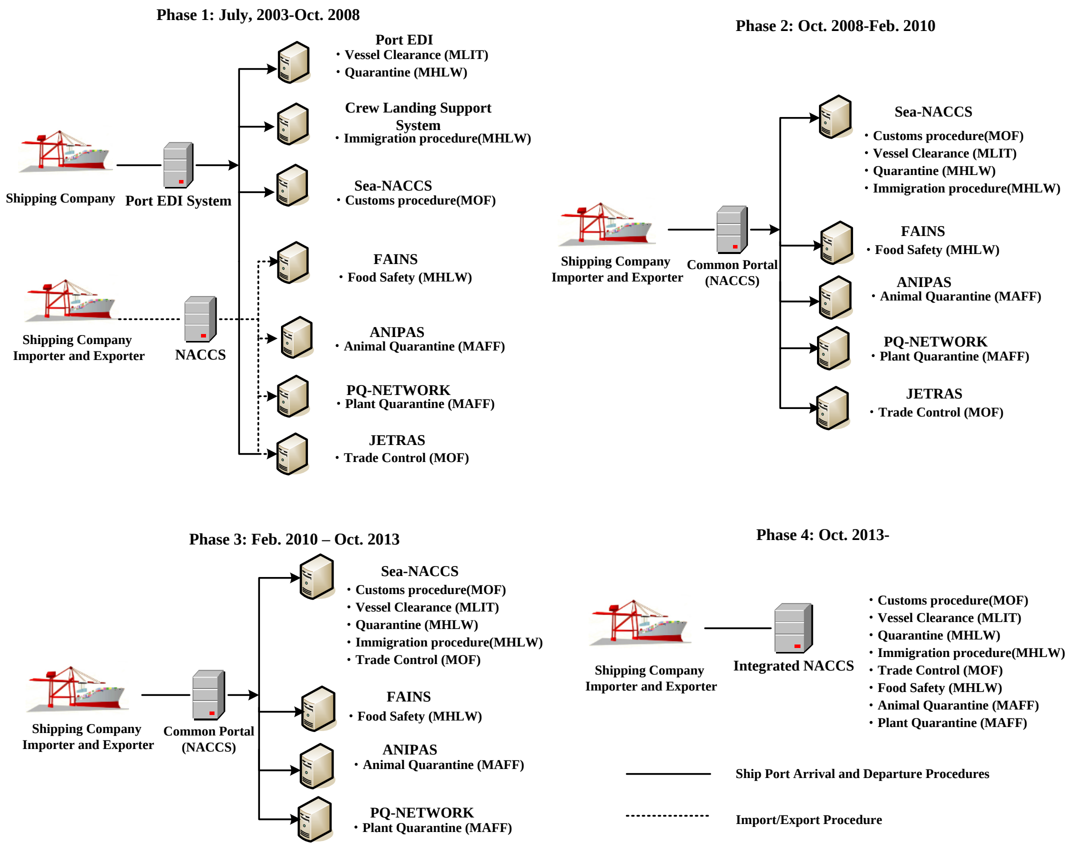


Figure 4.2: Single-window development processes of NACCS system integration

(Source: Japan Customs, 2015; Author edited)

Based on the survey statistics investigated by MOF in 2012, the average lead-time for general import marine cargo decreased to 2.5 days. The average time for customs declaration permitting decreased to 2.6 hours, which is assumed to be half the amount of time required in 2001 (MOF, 2012). The survey results are shown in Figure 4.3. Additionally, the survey's result for average import-container lead time is 2.5 days (60.7 hours).

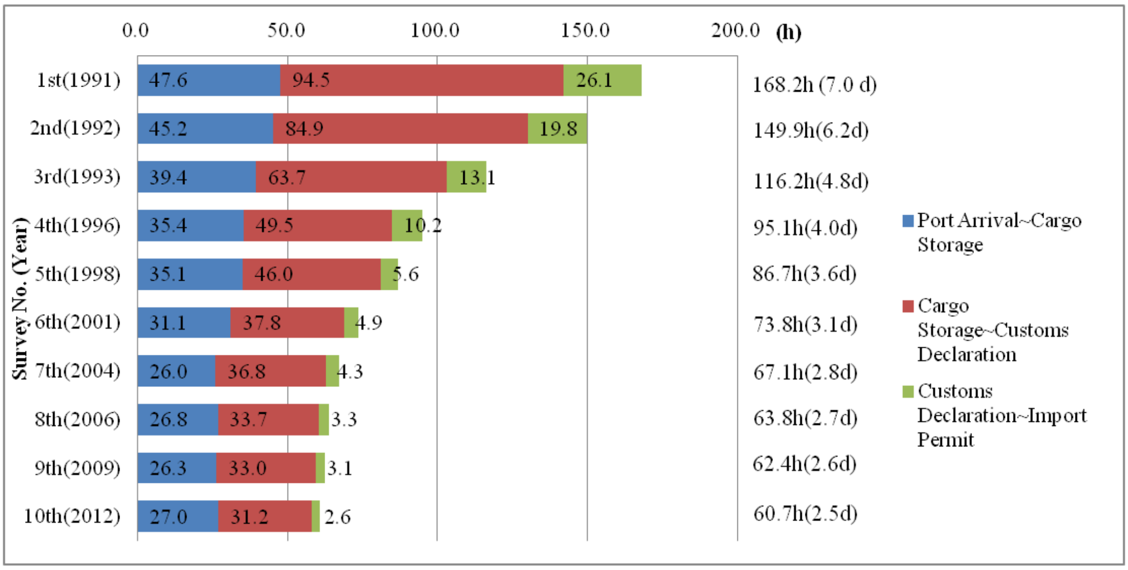


Figure 4.3: Lead time for general import marine-cargo procedures

4.3 Terminal Operating System

4.3.1 Cargo-handling Operation Processes in the Terminal

Foreign trade zones, also called free trade zones (FTZ), are a country's locations, which are situated "outside" of that country, which have acquired a special customs status. Goods can be shipped to such areas without being subject to the duties, quotas, and customs regulations of the host country. The goods can be warehoused in the FTZ until they are sent to their final destination either in the host or in a foreign country. Most of the world's ports are FTZs so that cargo can be unloaded from a ship, temporarily stored in a warehouse, and loaded onto another vessel to its final destination (Pierre, 2013). Therefore, relying on the advantages of their geography, low costs and speedy handling, several ports are successfully operating as global transshipment hubs, for example, the ports of Singapore and Korea.

Generally, trade cargo imported into a country through a port is warehoused in a bonded area under the jurisdiction of Customs until it is cleared and released. Because container terminals are the link in these international logistics, they are usually assumed to be FTZs.

As part of the processes shown in Figure 4.1, a typical transaction between the international-cargo process and the container terminal is as follows: the handling processes are shown in Figure 4.4 (export cargo flows are shown from steps 1 to 7 and import cargo flows, which are marked in brackets, are shown from steps 7 to 1):

[Step 1] Cargos are moved into the warehouse;

[Step 2] Cargos are stocked and sorted at the warehouse;

[Step 3] Cargos are packed (unpacked) into (from) the container;

[Step 4] Containers are delivered to the container terminal (warehouse);

[Step 5] Containers are checked at gate for move into (out of) the container terminal;

[Step 6] Containers are stored and handled at the container terminal, and

[Step 7] Containers are loaded (unloaded) onto (from) the ship.

(1) Move into warehouse

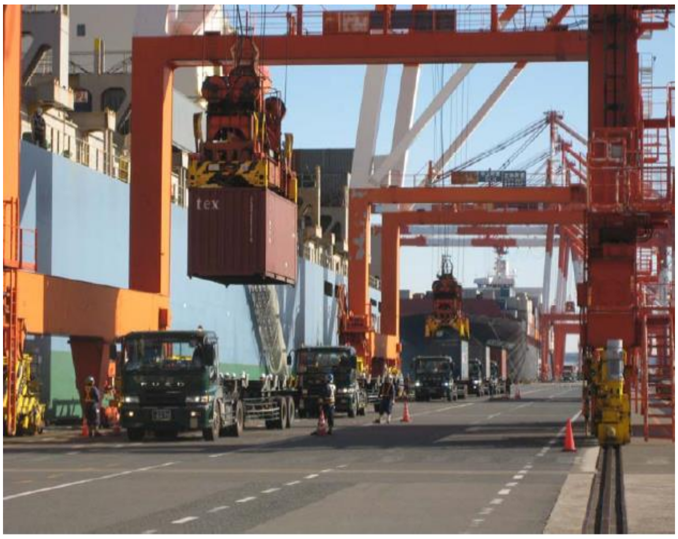
(2) Stock and Sort

(3) Pack into container

(4) Delivery to terminal

(5) Check at gate (6) Store and Handle at terminal



(7) Load onto ship

Figure 4.4: Handling processes for international cargo

(Figure Source: Meiko Trans Co., Ltd.)

As mentioned in Section 2.2.2, container terminals' layout and cargo-handling equipment may vary. In this section, the case of the Port of Nagoya is discussed. The cargo-handling processes and the terminal operating system adopted in the defined terminal are studied.

The Port of Nagoya is located at the center of the Japanese archipelago on the country's eastern coast facing the Pacific Ocean; the hinterland, Aichi Prefecture, is the home of Japan's automobile industry. The Port of Nagoya handles almost all types of cargo, e.g., general cargo, containers, bulk cargo, and machinery equipment. Because Nagoya is an integrated international port, its shipping lines connect to approximately 160 countries. The N Pier Container Terminal, which is the subject of this study, is one of the terminals at the Port of Nagoya. Imports of clothing, fiber products, and daily necessities and exports of automobile parts and industrial products from/to China and South Korea are the main cargo handled at the N Pier Container Terminal. Because of the geographically short distance between the port and its predominant trading partners, regular weekly vessels with small numbers of containers account for the majority of loads.

Steps 1 to 4 of N Pier's international cargo handling procedures occur at the warehouse near the container terminal. For steps 5 to 7, the general cargo-handling procedures for one ship are as follows: before the ship arrives, the export containers are gradually carried into the yard by truck; next, all of the export containers waiting for loading are gathered a few hours before the ship's arrival. While the ship is arriving at the berth, import containers are first unloaded onto trailers. Upon passing an appearance damage checking process, the containers are transferred to the yard storage blocks. After the unloading process, export containers are transferred from the TC yard to the quay by trailers that will be loaded onto the ship. After the ship leaves port, either the import containers will be removed sequentially after customs clearance by truck. An example of the container-handling flows at the terminal is shown in Figure 4.5.

Using the DGPS and RFID with other ICT technology, the movement information for the containers that are processed using cargo-handling equipment can be tracked and recorded in the terminal operating system that supports the terminal's overall operation processes.

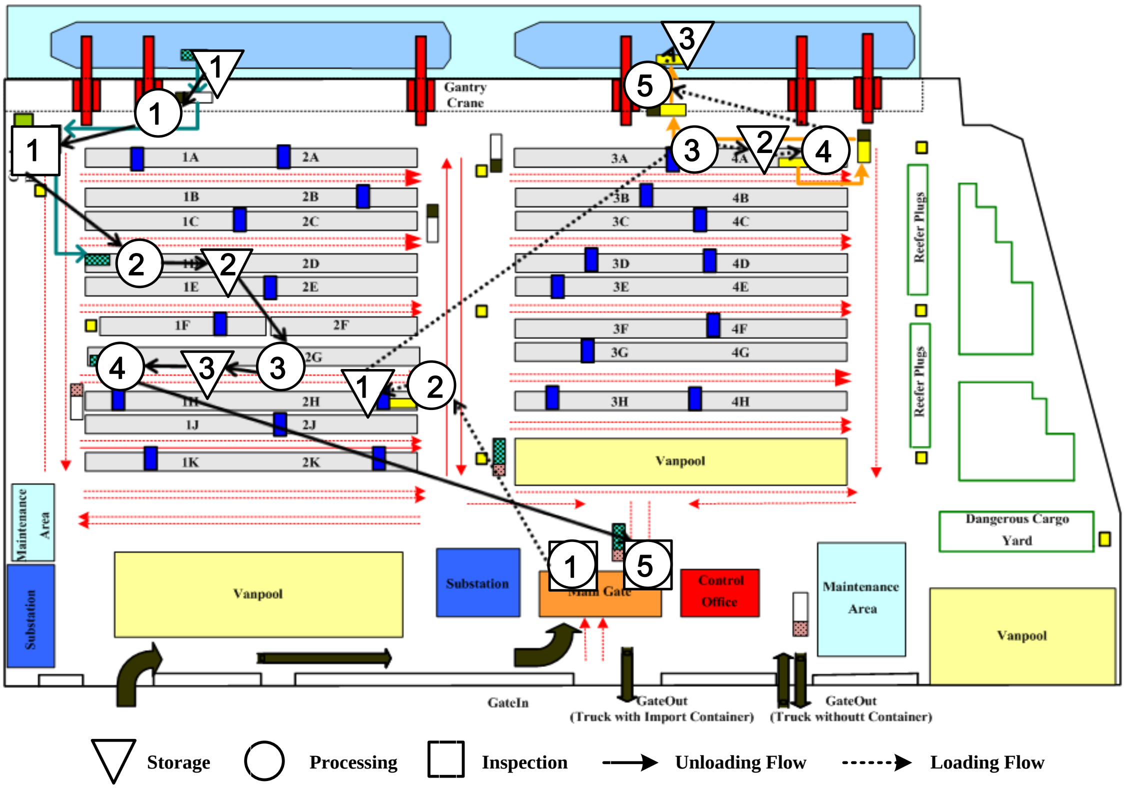


Figure 4.5: The terminal's facility layout and container-handling flows

4.3.2 Terminal Operating System – Nagoya United Terminal System as a Case

A terminal operating system is an integrated and fully automated software system designed to manage container terminals, to control delivery, storage, container processing and unloading operations at the container terminal, and to manage container documentation in real time (Yang and Takakuwa, 2015).

The yard is composed of the TC Yard for stocking general cargo and the SC Yard for stocking cargo that must be inspected. Most of the containers are stored in the TC Yard, which is usually divided into an export containers area (LD area) and an import containers area (UL area) for efficiently handling cargo. The operations in the LD area include receiving (R), which represents the terminal receiving an export container and loading (LD), corresponding to handling the container for loading onto the vessel. Conversely, the operations in the UL area include unloading (UL), when the container is unloaded from the vessel, and delivery (D), when the terminal delivers an import container to the cargo owner. Additionally, there are also shift (S) operations in these two areas, which can be primarily divided into the following categories: (1) Shift without trailer (SS), which usually refers to re-handling; and (2) shift with trailer (ST), which usually refers to moving the container under the shift plan. The overall operation processes in the terminal are supported by the terminal operating system.

The Nagoya United Terminal System (NUTS) is used as the information platform for all of the container terminals in the Port of Nagoya and supports the container ships, container-handling equipment and yard stock control. The NUTS system is composed of four subsystems, namely, the Control System (CS), Yard Planning System (YP), Yard Operation System (YO), and Vessel Planning System (VP) (Suzuki, 2002). The CS system serves as the host computer, controlling ship/cargo information and gate operations; in addition, it exchanges data with external systems. The YP system takes advantage of a graphical user interface (GUI) and is capable of establishing stacking plans for import and export containers and automatically designating the positioning of containers brought into the yard. The YO system gives instructions to cargo-handling equipment via task positions and priorities. Finally, the VP system is capable of forming plans for the vessel stowage and ship handling schedule. The NUTS framework and related operation flows in the terminal are shown in Figure 4.6. The system sends job-position information to the trailer/truck to tell the vehicle where to go and gives the process directive to the TC. In addition, the containers' movements in/out of the gate, shifting during the yard and loading/unloading to/from the ship are simultaneously recorded in the data file.

When a vessel arrives at berth, based on the unloading schedule, containers are unloaded by a gantry crane onto trailers that transfer them to the yard storage blocks. Once a container has been unloaded onto the trailer, information indicating unloading completion is transferred to NUTS. Shortly thereafter, handling instructions for containers/storage spots are sent to the yard cranes. However, instructions from NUTS allow the driver of the yard cranes to choose the next job in real time. Concurrently, NUTS records the time that handling is completed. Other operations inside the yard (S/D/R/LD) and basic information about the container and vessel are also recorded by the NUTS.

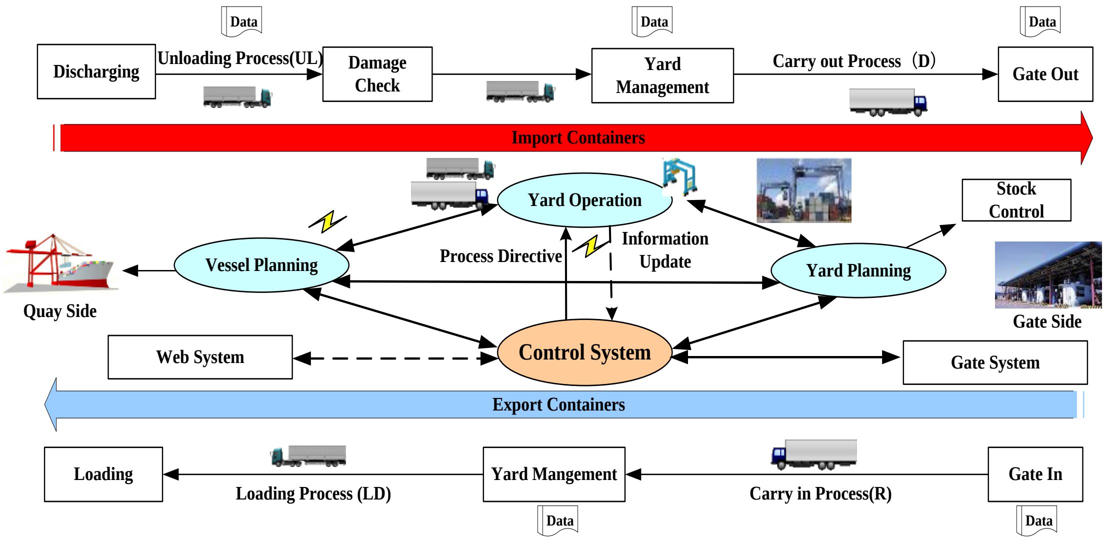


Figure 4.6: Framework of the NUTS and related operation flows

4.3.3 System Tracking Data

Cargo-handling equipment (including GCs, TCs, and SCs) inside trailers and external trucks are used in the N Pier Container Terminal. Basic information about the cargo and the operational data of the YCs are recorded in the system. In the export/import container-information file, each container's attributes (No., Size, Type, Height and Weight) were recorded, along with the handling data and time. Through the unique container ID, the entire dataset describing both the container-handling processes and information about the related ship can be obtained by binding the yard-operation data.

The data sample in the study is primarily based on 10 days' worth of data collected in 2011, and the ship information data is based on both former data and 13 days' worth of data collected in 2010.

A series of dataset examples extracted from the NUTS are shown in Table 4.2. The dataset describes the flows of an export container (No: UACU5209120), including the gate operation, yard operation, ship operation, and the ship information for which ship the container was loaded. From the data, UACU5209120 was carried by truck ER001 into the terminal gate at 2011/8/22 8:32. Because of the identification by the RFID, the attributes of UACU5209120 are known. Then, ER001 is instructed by the Control System to go to Block13, Bay 40/41, Row 6, and Tie 1 (B13-40/41-06-1). Simultaneously, TC No. 9 in the yard received the handling task. Six minutes later, the operation was completed. The container has been stocked in the yard until 2011/8/31; at 1:16, TC No. 19 received the handling task to load the container from B13-40/41-06-1 to trailer DX026, which will transfer the container to GC2. At 1:28, the operation was completed at the 21st in the loading sequence. Because the movements of GCs are not tracked by the system, the time the container was loaded by GC from DX026 to ship IBN HAZM is unknown. However, the container's location on the ship (Bay34, Row00, Tier84, Dock) is recorded (Yang and Takakuwa, 2014).

Table 4.2: The entire information of a container in the terminal

(a) Gate operation data;

Container No.	Size	Type	Height	Weight	Ship Name	Carrying Time
UACU5209120	40 ft	DC	9.6 ft	12793 kg	IBN HAZM	2011/8/22 8:32

(b) Yard operation data—receive container from gate to yard (R);

Task No.	Update Time	Reception Time	Container No.	Truck No.
G40759930500	2011/8/22 8:38	2011/8/22 8:32	UACU5209120	ER001

Operation Type	Complete Coordinates	Handling TC No.
R	B13-40/41-06-1	9

(c) Yard operation data—load container from yard to ship (LD)

Task No.	Update Time	Reception Time	Operation Type	Handling TC No.
S26966040500	2011/8/31 1:28	2011/8/31 1:16	LD	19

Original Coordinates	GC No.	Loading Sequence No.	Container No.	Trailer No.
B13-40/41-06-1	GC2	21	UACU5209120	DX026

(d) Ship operation data

Ship Arrives Time	Ship Name	Container No.	Bay	Row	Tier	Dock or Hold
2011/8/30 16:24	IBN HAZM	UACU5209120	34	0	84	D

(e) Ship information data

Ship Name	Ship Arrived Time	Ship Handling Starting Time	Ship Handling Completed Time	Ship Departure Time
IBN HAZM	2011/8/30 16:24	2011/8/30 16:30	2011/8/31 2:05	2011/8/31 2:20

Furthermore, by binding the table of the yard-operation data and the inventory data through the container No., the inventory period of the terminal's export/import containers can be obtained. Based on the statistics, approximately 50% of import cargo was carried out of the terminal within four days and approximately 76% of import cargo was carried out of the terminal within a week after being unloaded from the ship. This result is consistent with the import containers' customs-clearance lead time. The export containers are handled in the yard from approximately ten days before to at least one day before the ship arrives.

4.4 Summary

In this chapter, ICT applications used for customs clearance and terminal operational control are explained. The electronic customs-clearance system provides support and enabled the realization of quick document submission and processing at the terminal. Systems developments and upgrades are following a trend to integrate the overall authority responsible for the customs-clearance processes. In the case of Japan, the time spent performing customs-clearance processing for import cargos was shortened significantly through the implementation of a single-window system. Through the terminal operating system, the cargo and handling-equipment information at the terminal is visible and controllable, which makes it easy for the staff to operate and make arrangements. Considerable data were recorded in the system, and it is important to extract useful data from large and redundant datasets. The operation data of each piece of container-handling equipment can be sorted sequentially. Both the data tracked by DGPS and the statistics collected from the terminal can be processed to use as input data for constructing a simulation that will both solve the problem and improve the efficiency of container-handling equipment.

5 SYSTEM DATA ANALYSIS AND MODELING THE CARGO-HANDLING PROCESSES OF THE DISCHARGING PROCESSES

5.1 Introduction

Given the vast, complex and dynamic interactions among the various handling, transportation, and storage units, ICT systems are commonly used to assist and support seaport terminals' operations. Through the terminal operating system, operation instructions are given to the container-handling equipment: after the operation has been completed, the latest container information is updated to the system. Meanwhile, a large amount of the tracking data is recorded in the system during the daily operation, which requires that a solution be analyzed and used for capturing features of the system.

The goal in this chapter is to process and analyze the system data to capture the system features and obtain the input data for the simulation model. Section 5.2 clarifies the data-processing procedure of the yard cranes operation data that is recorded in the terminal operating system. The processing procedure is written in Excel VBA. Next, Section 5.3 introduces the features of the system and cargo-handling equipment, which are analyzed using the processed data.

In Section 5.4, a simulation model of the ship-unloading processes is constructed to examine the parameters obtained from the system data. A special-purpose data generator is developed to create experimental data for executing the simulation. The experimental data to be created include the number and attributes of the containers. The experimental result is compared to historical data for the ship-handling process. Next, a simulation analysis under various levels of activity is performed; the system's performance under various resource-arrangement principles is examined.

Consequently, this chapter is also studied to achieve Objective 2.

5.2 Data Processing and Analysis

5.2.1 Data Description

As described in detail in Section 4.3.3, the dataset obtained from the system includes ship operation information, yard operation and inventory information, and gate operation information. The data-processing procedure is provided using the example of the yard-operation data analysis.

Daily operation records of the TCs and SCs are stored in the yard-operation data file. There are 112 items of information about port operations recorded in the raw data, which contain overall information based on the operations processed by YCs during the day. However, the dataset also includes some redundant information such as the shipping code and blank row, which seem to add little value to the study. Therefore, the datasets must be processed both to clarify the system's working features and to obtain the input parameters. The operation code-changing rule is shown in Table 5.1. Most of the operation code meanings are detailed in Section 4.3.2. In this table, however, Code TU/TL means unloading/loading operations for the transshipment cargo, which was less than 1% of the cargo in the object terminal. Therefore, TU/TL are omitted and replaced by UL/LD. Furthermore, Code LC means that the location recorded was amended by staff and only the operation's completion time is recorded; therefore, these items are only used for completing the operation sequence, not for obtaining statistics about processing time.

For the yard-operation data, only the system instruction time (operation reception time) and completion time of the operation are recorded. The operation start time is unknown and thus, the actual operation processing time is unclear. To calculate operation start time, procedures for processing and integrating system data file records (TC yard) are implemented according to the steps set forth in the next section, and the program is written in Excel VBA. The data for an entire working day is used in the analysis.

Table 5.1: Operation code-changing rule

Type	Operation Code	Original Operation Code	Meaning
Delivery	D	D	Gate Out
Receive	R	R	Gate In
Unloading	UL	UL/TU	Discharging from ship
Loading	LD	LD/TL	Loading to ship
Shift	S	NI	Move with No Instruction
		SO	Shift Out(with trailer)
		SI	Shift In (with trailer)
		IS	Shift inside bay
		IB	Shift among bays
		RS/BS	Shift due to delivery
LC	LC	LC	Location Manual Input

5.2.2 Data Processing Procedure

The data-processing procedure for the yard-crane operation records is implemented in the following steps:

[Step 1] Extract the necessary data from the historical data file.

The items listed below are selected for further analyses:

(a) Operation No.;

(b) Container attributes: Container No., Size (20 ft. /40 ft.), and Type (Dry /Others);

(c) Vessel information: Vessel Code, Unloading Time (in the UL process) from the ship;

(d) Yard crane information: TC No., Operation Area;

(e) Operation information: Operation Code, Operation Instruction Time, Operation Completion Time, Original Coordinates, Destination Coordinates;

[Step 2] Change the Area Code to the standard form.

(a) Change the yard-column numbers A, B, C…(omitted)…H, J, K to 01, 02, 03…(omitted) …08, 09, 10, respectively (Facility layout as in Figure 4.5).

(b) The identification numbers of the yard blocks are modified to include digits up to the hundreds digit.

[Step 3] Change the time to the difference from 8:00 am (unit: second)

The primary purpose of steps 2 and 3 is to facilitate the calculations. One example of the data for the system processed after step 3 is shown in Table 5.2. In addition, TC may be transferred among the various blocks between two adjacent operations. Steps 4 to 6 are performed to calculate both TC transfer distance and operation start time.

Table 5.2: An example of the yard operation data

Operation No.	**Operation Completion Time**	**Operation Instruction Time**	**Operation Code**	**Container No.**	**Vessel Code**
i-1	3189	2986	D	TEMU2226XXX	HPRN
i	3471	3298	UL	SKHU9101XXX	DSAC
i+1	3734	3550	UL	SKHU9005XXX	DSAC

(1)

Container Size	**Container Type**	**Unloading Time**	**GC No.**	**Handling Equipment No.**	**Operation Block No.**	**Operation Bay No.**
20	DC	Null	Null	15	104	14
40	DC	3268	6	15	204	1
40	DC	3519	6	15	204	3

(2)

[Step 4] Calculate the TC transfer distance between the two adjacent operations.

(a) Clarify the container-stacking arrangement in the TC yard and move the patterns of the TC. Figure 5.1 shows the detailed arrangement of the containers in the yard blocks and the TC movement patterns. There are two TC movement patterns: horizontal movement (moving in a row) and vertical movement (moving across the row). Additionally, the following five types of possible calculation situations are shown in Figure 5.1:

- Pattern A: Horizontal move

(1) Move inside the bay

(2) Move among the bay

- Pattern B: Vertical move

(3) Move across the row

(4) Move across the row

(5) Move across both the bay and row

(b) Calculate the TC transfer distance in each possible situation using the method shown in Figure 5.2. If the length of one slot equals 6.5 m, the TC transfer distance can be obtained by calculating the difference of the slot numbers between the two adjacent operations.

(c) Calculate the TC transfer time based on the distance. The transfer time is calculated by transferring the distance and TC travel speed. The method is also shown in Figure 5.2; there is a 90-second safety confirmation time in the vertical transfer. The calculation program is written in VBA code.

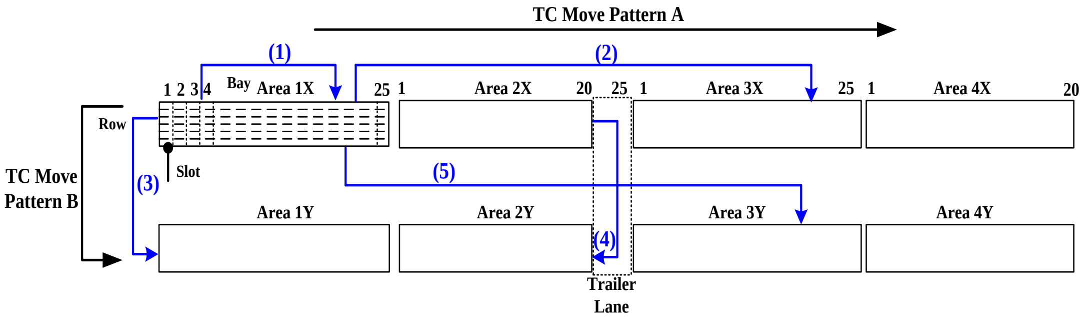


Figure 5.1: Arrangements of yard blocks and TC move patterns

[Step 5] Calculate the earliest operation start time.

There are two cases for the timing for which system provides instructions: the system may provide a new instruction before the most recent task is completed, a situation noted as (a), or after all of the tasks are completed, a situation noted as (b). The two cases are shown in Figure 5.3.

If TC moves from Operation i to Operation $i+1$,

Set

HD = Horizontal Distance (unit: slot), VD = Vertical Distance (unit: slot);

ABS = Absolute Value, a = Area No. (1~4), b = bay No. (1~25), r = Yard Row No. (A~K; 1~10)

Set the Area No. Large One as a_m, and its bay No. as b_m; and set the Area No. Small One as a_n, its Bay No. as b_n.

Transfer Distance:

Move Pattern A (Only HD):

(1) TC moves inside the same area,

$$HD = \text{ABS}\ [b(i+1) - b(i)]$$

(2) TC moves among the different areas,

$$HD = [(a_m - a_n - 1)*25] + [\ \text{ABS}\ (25 - b_n) + b_m]$$

Move Pattern B (VD and HD): $VD = \text{ABS}[\ r(i+1) - r(i)]$

(3) $a(i+1) = a(i) = 1$ or 3

$$HD = b\ (i+1) + b\ (i)$$

(4) $a(i+1) = a(i) = 2$ or 4

$$HD = 20 - b\ (i+1) + 20 - b\ (i)$$

(5) $a\ (i+1) \neq a(i) = 2$ or 4

$$HD = [(a_m - a_n - 1)*25] + [\text{ABS}\ (25 - b_n) + b_m]$$

Transfer Time:

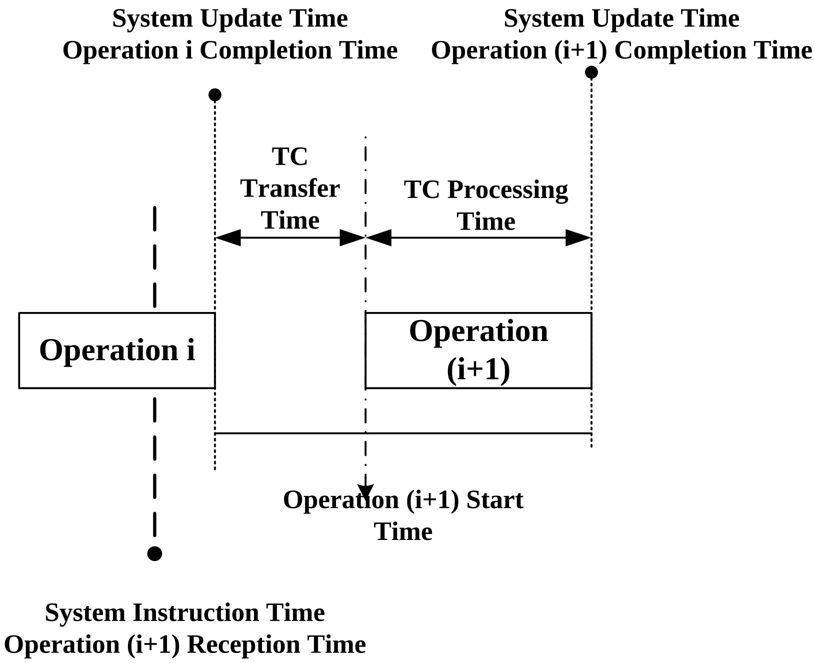
TC Transfer Time = *Horizontal Transfer Time* + *Vertical Transfer Time*

TC Transfer Speed = 2.25 m/s, Length of 1 Slot = 6.5 m

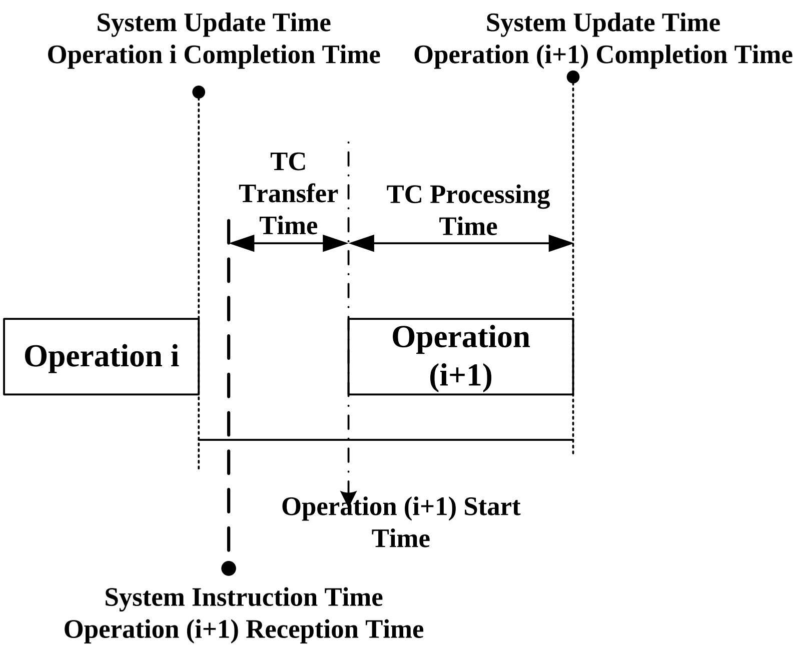
Horizontal Transfer Time= (HD*6.5)/2.25 (second)

Vertical Transfer Time = 90+VD*15 (second)

Figure 5.2: The method for calculating the TC transfer distance and transfer time



(a) The system outputs a new instruction before the latest task is completed



(b) The system outputs a new instruction after all of the tasks are completed

Figure 5.3: Two cases of timing for which the system gives instructions

(a) Operation (i+1) Start Time = Operation (i) Completion Time + TC Transfer Time

(b) Operation (i+1) Start Time = Operation (i+1) Reception Time + TC Transfer Time

[Step 6] Calculate the yard-crane processing time and the operation window.

(a) TC Processing Time (i) = Operation (i) Completion Time – Operation (i) Start Time

(b) TC Operating Time (i) = TC Processing Time (i) + TC Transfer Time (i)

[Step 7] Move the processed data to a new sheet.

For the purpose of implementation, the programs were written in VBA. The processed data are used for the analysis. The user interface of the VBA is shown in Figure 5.4.

5.2.3 Data Analysis

As mentioned above, there are two main objectives when analyzing the processed data. The first objective is to capture the system features, and the second objective is to generate the model input data. After analyzing the data for the yard-operation and yard-inventory files, the following system features are shown:

(1) Container types and proportion in the terminal

There are five types of containers used at the terminal: (1) the dry container (DC), which is the most commonly used container; (2) the reefer container (RC, which should be stocked in the reefer plug area); (3) the flat-rack container; (4) the open-top container; and (5) the tank container (TaC, which should be stocked in the dangerous cargo area). The proportion of each type of container is presented in Table 5.3.

From Table 5.3, it can be seen that approximately 95% of the import and approximately 97% of the export containers in the terminal are DCs. The proportion of 20 and 40 feet in the import containers is approximately 1:1, and that proportion in the export containers is approximately 1:1.15. Therefore, although this is a specifically analyzed case, non-DC container can be omitted from the study.

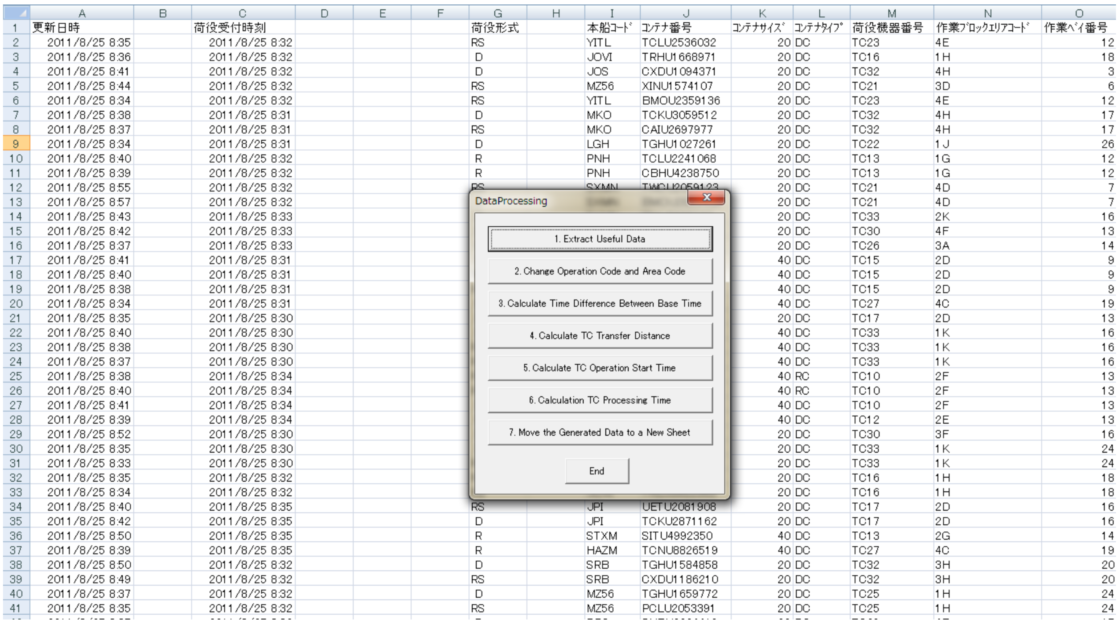


Figure 5.4: VBA user interface for data processing

Table 5.3: Proportion of the containers

	Type	DC	RC	TaC	Other
Import	20 ft.	47.87%	0.83%	0.84%	0.63%
	40 ft.	47.32%	1.68%	0.00%	0.84%
Export	20 ft.	45.09%	0.94%	1.35%	0.61%
	40 ft.	52.01%	1.97%	0.00%	0.74%

(2) The features of the TC transfer pattern

Based on the statistical analysis, TC vertical movement proportion accounted for only approximately 0.5% of daily operations because the safety confirmation takes so much time. In addition, the average horizontal transfer distance is 5 slots, which indicates that the average TC transfer time per operation is 14.4 seconds. The average transfer time is added to the TC processing time per operation.

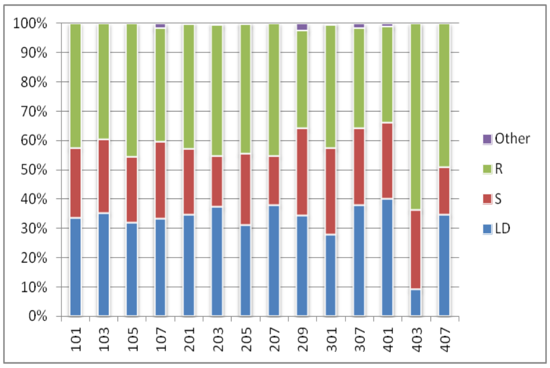
(3) The proportions and operation types in the blocks

The proportions of operation types in each block are shown in Figure 5.5. The UL and LD areas can be divided using the statistics. The result shows that in the current system, the UL/LD containers tend to be stored in different cross lines. Additionally, the UL area is much greater than the LD area in terms of numbers because the UL cargo occupies a greater share of the terminal during the data period.

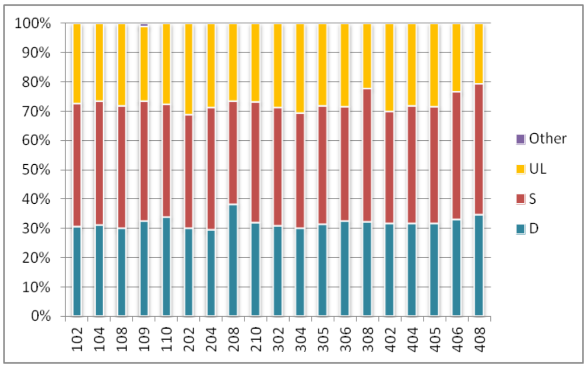
Based on the position and operation type in the area, the block number can be integrated as two numbers to one block, as in Table 5.4.

(4) Cargo-handling equipment processing time

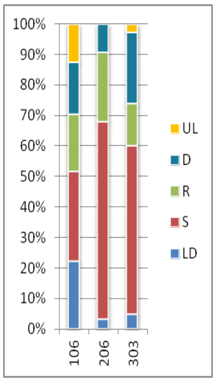
The processing time obtained for TC and GC is analyzed using Input Analyzer. Distributions with their parameters were determined with respect to minimum squared errors based on the Chi-square test of the input analyzer. The cargo-handling equipment processing time is shown in Table 5.5.



(a) LD area



(b) UL area



(c) Mix area

Figure 5.5: Proportions of operation types in each area

Table 5.4: Yard-area grouping and block number

Area Type	Area No.	Block No.	Area No.	Block No.
LD Area	101, 201	Block 1	301, 401	Block 11
	103, 203	Block 3	307, 407	Block 17
	105, 205	Block 5		
	107, 207	Block 7		
UL Area	102, 202	Block 2	302, 402	Block 12
	104, 204	Block 4	304, 404	Block 14
	108, 208	Block 8	305, 405	Block 15
	110, 210	Block 10	306, 406	Block 16
			308, 408	Block 18
Mix Area	106, 206 (RC)	Block 6	303, 403	Block 13
	109, 209	Block 9		

Table 5.5: Cargo-handling equipment processing time

Items	Processing Time (unit:second)	
Gantry Crane	27 + Erlang(28.4, 3)	
Transfer Crane	20 ft.	30 + Erlang(26.3, 3)
	40 ft.	36 + Erlang(27.7, 3)

5.3 Data Generator

To verify the data and parameters collected from the ICT system, a numerical experiment is implemented through a simulation model of a ship with a single GC unloading process case. The model's input data are generated by a special-purpose data generator.

The number of containers that must be handled in a terminal can change based on factors such as seasonal variations of cargo, fluctuations in exchange rates, etc. The proportions of the mix of types and sizes may change in the actual system. A special-purpose data generator is designed and developed to create experimental data in the study. The data generator is written in Excel VBA. The experimental data created contain the load factor, the vessel number, the container type, and the size.

The overall flow of the data generator proposed in this study can be summarized as follows:

(a) Specify a percentage of container or increase compared with the baseline condition;

(b) Specify the headings of A1 through D1;

(c) Number the container in column A;

(d) Specify the no. of the vessel in column B;

(e) Specify the size of the container in column C;

(f) Specify the type of the container in column D.

A similar idea for the data generator for simulation experiments appears in simulations of warehousing at the distribution centers, international-departure flights at airports, and emergency departments at general hospitals (Takakuwa et al., 2000; Oyama and Takakuwa, 2003; Takakuwa and Shiozaki, 2004). The required input parameters are percentages that correspond to increases or decreases compared to the baseline condition on the 100 containers/ship that are being unloaded and a percentage of each size and type of containers. The interface of the data generator is shown in Figure 5.6. By inputting these parameters, the corresponding container handling list is created. Table 5.6 shows a sample output created by the proposed data generator. The generated data includes the ship number and the size and the type of the container. Other types of the containers are omitted in this study. By utilizing these generated data as an input file for the simulation model, experiments can be conducted under any specified condition.

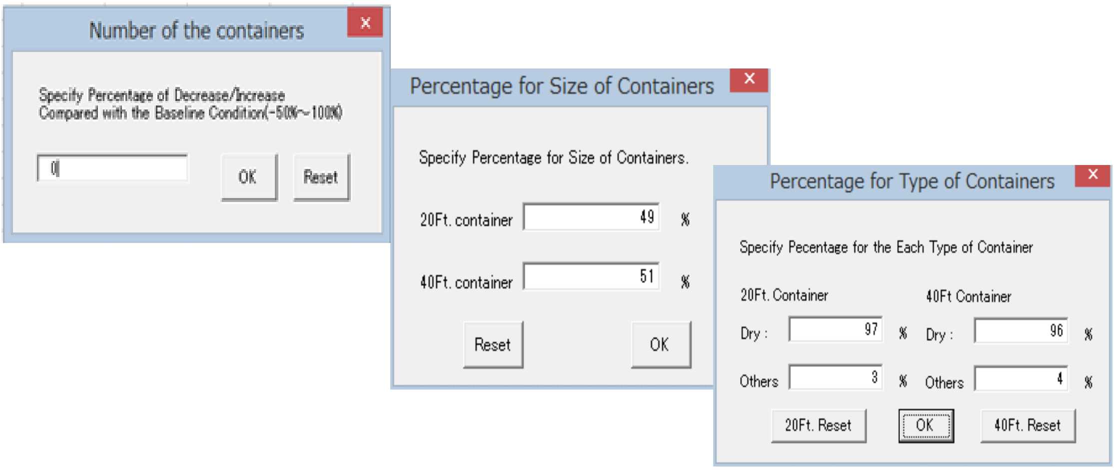


Figure 5.6: Interface of the data generator.

5.4 Application

5.4.1 Simulation Model

A simulation model for the terminal's discharging process was constructed in this section to test the parameters obtained from the system. The handling flow of the import containers is shown in Figure 5.7. A container is unloaded by the GC and temporarily stocked in the yard. The experimental parameters of the terminal and handling equipment obtained from the processed data are shown in Table 5.7.

Table 5.6: Sample of the generated data

No.	Ship No.	Size	Type
1	1	0	1
2	1	0	1
3	1	0	1
4	1	0	1
5	1	1	1
6	1	1	2
7	1	0	1
8	1	1	1
9	1	1	1
10	1	0	1
omitted			

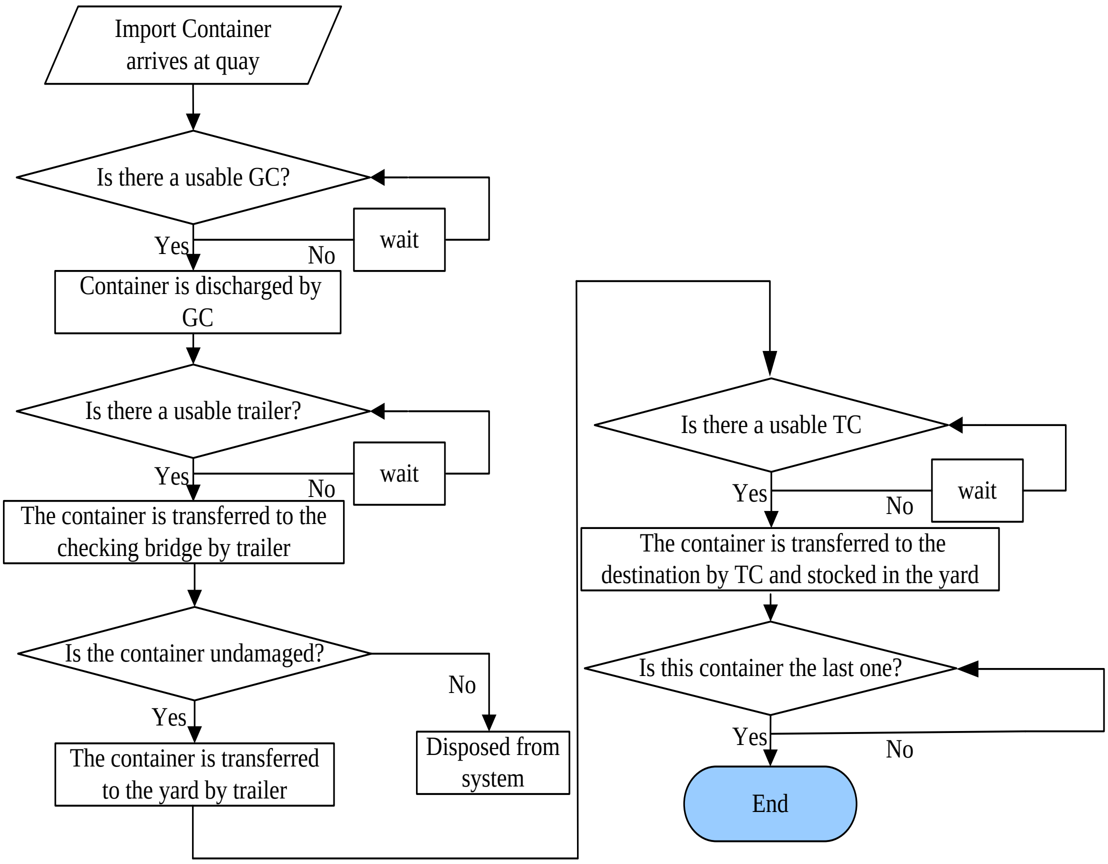


Figure 5.7: Handling flows of the import container.

Table 5.7: Experimental conditions and parameters

Items	Descriptions	Parameters		Unit
Gantry Crane	Number of units held	1		(units)
	Processing Time	27 + Erlang(28.4, 3)		(second)
Check Bridge	Number of units held	1		(units)
	Processing Time	Triangular(26, 30, 32)		(second)
UL Block	Number of units held	No.2 (1B, 2B), No.4 (1D, 2D), No.8 (1H, 2H), No. 9 (1J, 2J), No.10 (1K, 2K), No.12 (3B, 4B), No.14 (3D, 4D), No.15 (3E, 4E), No.16 (3F, 4F), No.18 (3H, 4H)		
Transfer Crane	Number of units held	1		(unit/block)
	Processing Time	20 ft.	30 + Erlang(26.3, 3)	(second)
		40 ft.	36 + Erlang(27.7, 3)	(second)
Trailer	Number of units held	4		(units/GC)
	Travel speed	20		(km/h)

5.4.2 Verification and Validation

A simulation model in this study was conducted using the modeling software Simio (Kelton et al., 2013). The 3-D animation provides an efficient mechanism to assist in model verification.

Validation of the model is based on comparing the experimental results of the ship-discharge time obtained from running the simulation model to the historical statistics recorded in the next section.

5.4.3 Experiments

In this section, the above-mentioned procedures for preparing simulation data explain the process of obtaining the ship discharging times using numerical examples. Consider a case of 100 boxes per ship—20 Ft.: 40 Ft. =1:1, dry container 100%—as a typical case in the discharging process. In this case, the associated area, including both the apron (GC1) and the UL blocks, was included in the simulation model used to examine the discharging flows and to collect the ship discharging statistics.

The evaluation indicators of trailer travel time and ship discharging time are included. Trailer travel time is defined as the time interval required for the trailer to take the container from the GC to the yard block where the container is unloaded. Ship discharging time is defined as the time interval required from the first container unloaded onto the trailer to when the last container enters the yard block.

As the experimental conditions of the experiment, the numbers of the import containers are specified as 1.00, 1.20, 1.40, 1.60, 1.80, and 2.00 times the baseline. The defined-operation blocks are divided into 5 groups: 1 block (No. 2), left 5 blocks (Nos. 2, 4, 8, 9, 10), front 5 blocks (Nos. 2, 4, 12, 14, 15), right 5 blocks (Nos. 12, 14, 15, 16, 18), and the ten total blocks. Thus, twenty replications of the simulation model are performed.

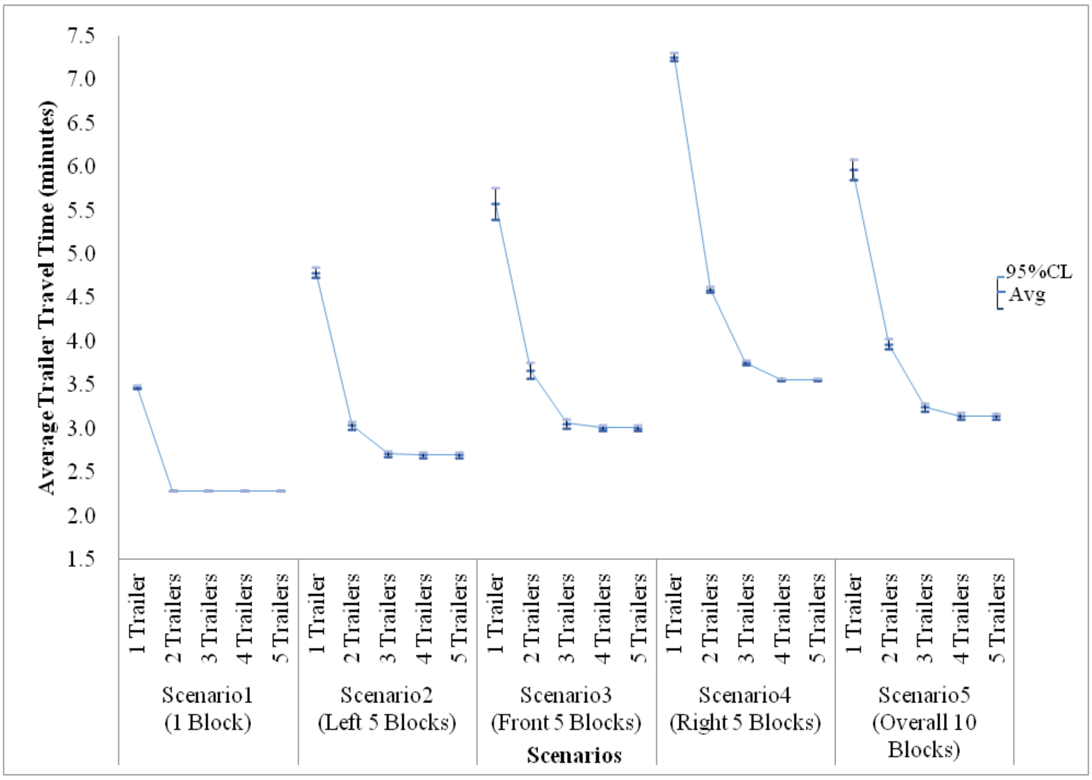


Figure 5.8: The trailer travel time.

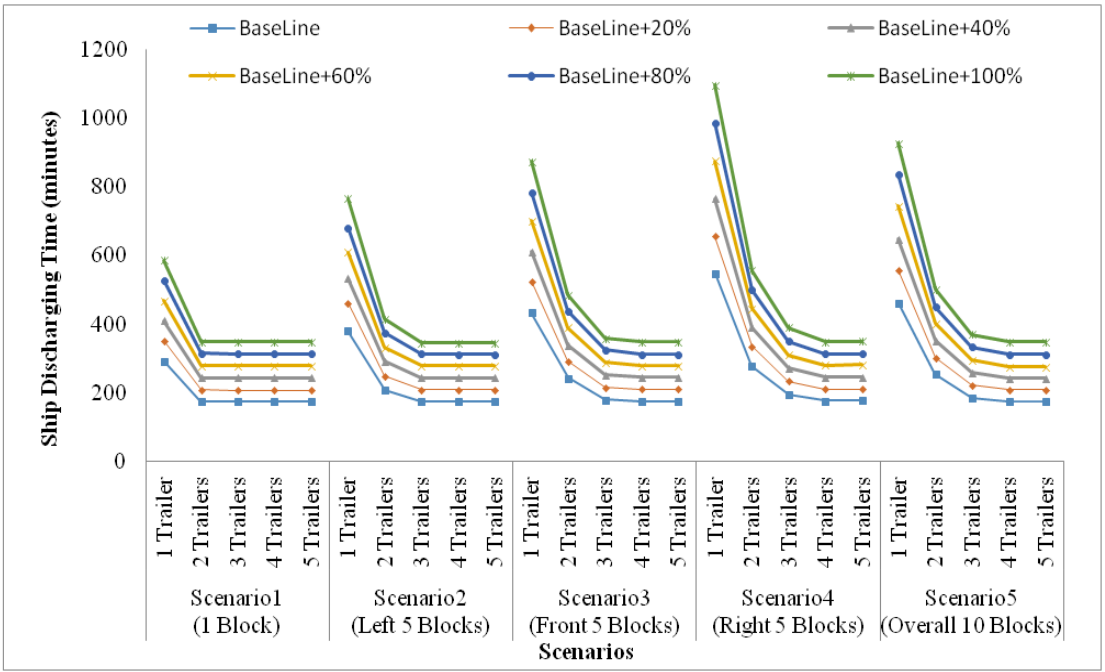


Figure 5.9: The ship discharging time.

After twenty replications of the simulation experiments under the specified conditions are executed, a 95% confidence interval for the average trailer travel time is obtained, as shown in Figure 5.8. Furthermore, the average ship discharging time is shown in Figure 5.9. From Figure 5.9, the ship discharging time trends toward stabilization in all scenarios regardless of the position of the UL block. The average ship discharging time among the scenarios is 175.33 minutes. Based on the historical data and operational experience of the staff, the average GC handling productivity in the N terminal is 35 boxes/hour. Thus, the discharging time for 100 container boxes is 171.42 minutes, and the difference in the experimental data is approximately 2.2%, which is less than 5%. Therefore, the parameters can be considered to present the system features.

From Figure 5.8, the time is effectively shortened effectively by increasing the trailer number to 3 units, except for Scenario 1. In addition, when the trailer number is up to 4 units, only the time in Scenario 4 is significantly shortened. There is almost no difference among the scenarios when the trailer number is increased to 5 units. From

Figure 5.9, the ship discharging time changes very little between scenarios 2 and 3 when the number of trailers is increased from three to four units. The ship discharging time assumes that three trailers can complete the tasks in the shortest time if the import container can be unloaded in the blocks among the left and front areas. In this case, the remainder of the trailers either can be arranged to serve other GCs or can be considered to decrease the total number of trailers used during the ship handling operation.

5.5 Summary

In this chapter, the yard operation data recorded in the terminal operating system is processed using a developed VBA program. The processed data are used to capture for the system's working features and to obtain the simulation's input parameters. Next, a simulation model for the ship discharging process of the container terminal is constructed and a special-purpose data generator is developed that will create experimental data to examine the processed data. Furthermore, the flows of the import containers under the various levels of activity were examined to execute the simulation experiments under various activity levels. The system performance is compared by implementing the simulation model. Consequently, the proposed procedure for processing system data and creating input parameters for the model can be used as a model to forecast and evaluate port operation.

6 A SIMULATION-BASED ANALYSIS OF THE CARGO-HANDLING EQIUPMENT ALLOCATION ON A CONTAINER TERMINAL

6.1 Introduction

Because the amount of international trade is continuously increasing, maritime container terminals, which serve as hubs for temporary container stocking either for journeys from sea to sea or for journeys to the hinterland, play an important role in global logistics. To increase operating profit and satisfy customers, container terminals are required to serve ships as quickly as possible despite their limited handling space and equipment. Therefore, optimizing and balancing the customer's need for quick service against the economical use of equipment is the main problem in port management (Sgouridis and Angelides, 2002).

Because it would be prohibitively costly and difficult to perform the experiment with an actual port system, a simulation model was constructed to obtain solutions to the problem. For improving handling equipment efficiency, simulation analysis is performed for the trailers that served gantry cranes for ship operation (container loading and unloading processes) by comparing the different dispatching scenarios after performing the simulation.

In this chapter, the simulation analysis of the cargo-handling equipment allocation problem is studied. Section 6.2 studied the problem of the vehicle-allocation strategy to the GC during the ship handling process. The efficiency and the flexible dispatching method of the trailers that served the GCs are analyzed by executing different simulation scenarios, and a reasonable resource dispatching policy is recommended.

6.2 Vehicle Dispatching Problem

6.2.1 Problem Description

In a container terminal with an YC system, the containers must be transported from the ship to the yard stacks and vice versa. The problem of choosing the type of horizontal transport equipment is a strategic-level decision when a terminal is being designed and constructed. As mentioned in Section 2.2.3, several types of equipment, such as trailers, AGVs, SCs, forklift trucks, ALVs, etc., can be used. At the operational level, however, vehicle routing and scheduling is the problem that must be solved (Vis and Koster, 2003). Because automatic vehicles (reviewed in Section 3.2.2) are controlled by predefined procedures, they are the study objects with the most references. Furthermore, because trailers are the relatively low-cost handling equipment, the number of AGVs or ALVs is usually set as a large number in the experimental system.

This section studies a solution to the problem of dispatching vehicles that aims to dispatch a limited number of trailers that served GCs to transfer containers from/to the yard for ship handling operation at quayside. The model considers the case of ship handling processes with one berth and multiple GCs.

Manned handling equipment is employed in the system. Four trailers are usually employed to serve one GC during the ship handling operation. A better dispatching policy with current resources is being considered. With equipped in-vehicle terminals, it becomes possible to give operation position instructions to the trailer. Therefore, the proposal to increase the flexibility of the trailers is being considered by port managers. For the economics of experimentation, the effect is evaluated and analyzed using the performing simulation model.

During the ship handling operation, each container that needs to be transferred during the shipping operation is referred to as a job. For a one-berth, multi-crane model, the loading process is assumed to be implemented after the discharging process is complete. The greedy dispatching method, in which the current job is dispatched to the first available trailer, is adopted in this study. The greedy algorithm is demonstrated as the near-optimal method in the single GC model, and it performs reasonably effectively in situations involving multiple cranes (Bish et al. 2005). Although the greedy dispatching method is not the optimal method for the multiple GC model, this method is an appealing solution because of its simplicity, which makes it easy to perform for real-time control.

Additionally, in the objected terminal, as shown in Table 5.4, import and export containers are usually stacked separately and placed in the interlace blocks. The various blocks are marked in Figure 6.1.

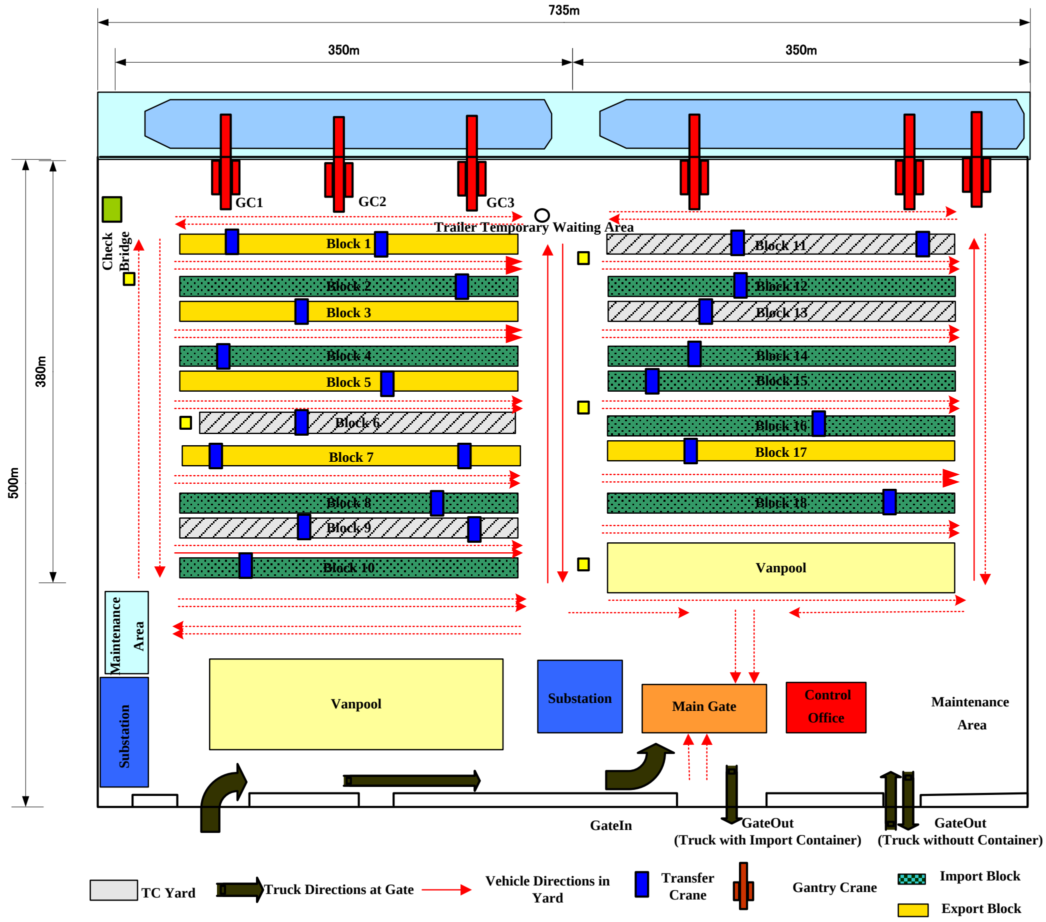


Figure 6.1: Object-terminal facility layout

6.2.2 Assumptions

Adopting the premise of keeping the features of the system, this study makes several assumptions when constructing the simulation model.

The case of a berth mooring a single ship with three GCs is considered in the model. Although in the object terminal, the ship is usually handled by one or two GCs, this case can be considered because two ships are simultaneously handled in one berth. The ship is assumed to be a medium-load ship. The arrival interval and container numbers for the ships are assumed to observe the statistical distribution.

Discharging and loading sequence is considered as predefined in the simulation. In the real terminal, the vessel plan is made in advance based on information about the ship stowage and container list. Before a ship arrives at the terminal, export containers are usually gathered together in the block relatively close to the quay for ease of handling. Although the container-stacking plan is also a decision problem in the terminal, for our objective of studying trailer operational efficiency, import containers are assumed to be stacked and ready for shipment. After the ship is moored at the berth, the import containers are unloaded from ship according to the predefined loading sequence. Additionally, it is assumed that the loading job can only be implemented after all of the GCs' unloading jobs have been completed.

In this study, the proportion containers size is assumed to be 20ft.:40ft., dry containers. Furthermore, each trailer available in the terminal is allowed to carry one container at a time. The time of the trailer travel is based on the distance in the terminal and the velocity of the trailers.

The yard is divided into UL blocks for stocking import containers and LD blocks for stocking export containers. The division of the blocks varies according to the scenario, the better to investigate the effect of the work area. The number of yard cranes employed in the terminal is assumed to be one TC in one block, and the failure of the TC is not considered.

Because the cargo owner may arrive to retrieve its container at any time that the terminal is open. Therefore, except for UL and LD operations, the operations considered in the yard during the ship handling process are the D operations in the UL blocks. Considering the priority of ship handling, UL operations have priority over D operations.

However, if a TC is processing a D operation when a trailer carries a UL container to the block, the trailer must wait until the D operation is completed. Furthermore, it is assumed that no other kind of job needs to be implemented in the LD blocks during ship handling.

Consequently, the study’s main assumptions are as follows:

- Three GCs serve 1 ship at a berth. Twelve trailers serve the GCs.
- The Proportion of the container size is 20 ft.: 40 ft. = 1:1.
- For each GC, there is a predetermined job sequence, including an unloading job and a loading job. A loading job can only be implemented after all of the GCs’ unloading jobs have been completed.
- Export and import containers are stocked at different blocks in the yard. In the UL blocks, except for UL operations, D operations may occur during the ship handling process, whereas only LD operations occur in the LD blocks.
- The trailers’ temporary waiting area is between the quay and yard, and this area can be observed in Figure 6.1. The trailers will return to the waiting area when they are idle.
- Each trailer can only carry one container at a time.
- The proficiency of the operators who drive the GCs, TCs, and trailers has no influence on the system.

6.2.3 Performance Measure and Input/Output Data

The simulation model is developed to analyze the vehicle dispatching policy and the layout division effects on the efficiency of ship handling processes. For this purpose, the total ship dwelling time of a constant number of the ships is considered as the main performance measure in the terminal, which can be described as the *number of containers handled* during a defined period in the simulation experiment.

In the experiment, the terminal's capacity and layout are the substantially observed scope of the N pier container terminal. Only the TC yard with the blocks is considered. Assume that there are 18 rectangle blocks and 45 bays in a block; additionally, each bay consists of 6 rows by 4 ties. The arrival interval of the ships and the processing time of the handling equipment use the statistical distributions, which imitate the real processing times. Processing for the real data is detailed in Sections 5.2 and 5.3. Additionally, the input data for the D operation are defined to observe the arrival rates of external trucks during the terminal's opening hours based on the real system data, as in Figure 6.2. Furthermore, some distributions and parameters are shown in Table 6.1.

The output data for the simulation is the total number of the container handled during the experiment lengths.

Starting Offset	Ending Offset	Rate (events per hour)
Day 1, 00:00:00	Day 1, 01:00:00	31
Day 1, 01:00:00	Day 1, 02:00:00	75
Day 1, 02:00:00	Day 1, 03:00:00	86
Day 1, 03:00:00	Day 1, 04:00:00	86
Day 1, 04:00:00	Day 1, 05:00:00	113
Day 1, 05:00:00	Day 1, 06:00:00	90
Day 1, 06:00:00	Day 1, 07:00:00	127
Day 1, 07:00:00	Day 1, 08:00:00	111
Day 1, 08:00:00	Day 1, 09:00:00	142
Day 1, 09:00:00	Day 1, 10:00:00	54
Day 1, 10:00:00	Day 1, 11:00:00	5
Day 1, 11:00:00	Day 1, 12:00:00	2
Day 1, 12:00:00	Day 1, 13:00:00	0
Day 1, 13:00:00	Day 1, 14:00:00	0
Day 1, 14:00:00	Day 1, 15:00:00	0
Day 1, 15:00:00	Day 1, 16:00:00	0
Day 1, 16:00:00	Day 1, 17:00:00	0
Day 1, 17:00:00	Day 1, 18:00:00	0
Day 1, 18:00:00	Day 1, 19:00:00	0
Day 1, 19:00:00	Day 1, 20:00:00	0
Day 1, 20:00:00	Day 1, 21:00:00	0
Day 1, 21:00:00	Day 1, 22:00:00	0
Day 1, 22:00:00	Day 1, 23:00:00	0
Day 1, 23:00:00	Day 2, 00:00:00	0
Day 2, 00:00:00	Day 2, 01:00:00	43
Day 2, 01:00:00	Day 2, 02:00:00	95

Figure 6.2: Rate table of delivery operation

Table 6.1: Parameters of the simulation model

Berth		**Block**	
Capacity	1 (ship)	Number of units held	14 (units)
Gantry Crane		UL block No.	2,4,8,10,12, 14,15,16,18
Number of units	3 (units)		
Processing time	27 + Erlang (28.4, 3)	LD block No.	1, 3, 5, 7, 17
Check Bridge		**Ship**	
Number of units held	1 (unit)	Load size	Triangular (205,320,499) (boxes)
Processing time	Triangular (26, 30, 32) (second)	Import proportion	55 (percent)
Transfer Crane		**Trailer**	
Number of units held	1 (unit/block)	Number of units held	12 (units)
Processing time	20ft.: 30 + Erlang (28.4, 3) (second)	Travel speed	20 (km/h)
	40ft.: 36 + Erlang (28.3, 3) (second)	**Gate open hour**	8:00-19:00
Workdays	6 (days/week)	**Berth open hour**	24h

6.2.4 Simulation Model

The simulation model of the ship handling processes in the container terminal is constructed using the Simio modeling software, version 7.114. Based on the container-handling processes of the real container terminal, an original simulation model, which is called the as-is model, is constructed to analyze the current system. The simulation model in this study is conducted using Simio modeling software. Figure 6.3 shows the main logic chart for the simulation model.

The logic chart consists of four main parts that control the model: (1) ship arrival logic; (2) discharging process logic; (3) loading process logic; and (4) ship departure logic.

In the ship handling processes logic, the first part of the logic chart is the container ship's arriving logic, designed such that the ship arrives at the berth and creates the containers that need to be handled. The number of GCs that are responsible for handling the container assigned to the container attribute is also determined. The second part is the unloading process logic, which is designed to execute the ship-unloading process. After checking that all of the import containers have been unloaded from the ship, the process can proceed to the next part. The third part is the loading process logic, which is designed to execute the ship-loading process. After checking that all the export containers have been loaded on a ship, the last part is the ship departure logic, which is used to develop the necessary statistics to analyze the system performance and vehicle efficiency. In the second and third parts of the process logic, part of the greedy dispatching method is highlighted.

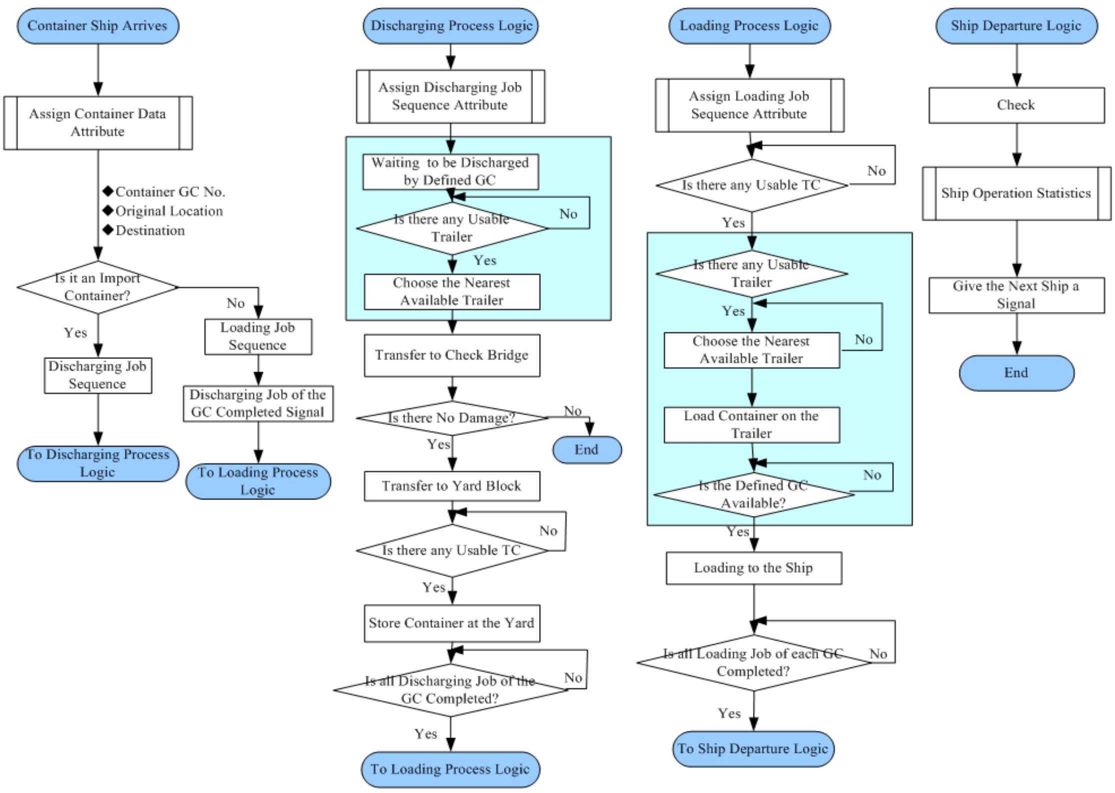


Figure 6.3: Logic chart for simulation model

After the simulation model has been developed, verification of the model is necessary. By running the simulation model, the container-handling processes can be understood visually. Furthermore, the model can be executed continuously for a long period and multiple times. Three-dimensional animation is supported as a part of the modeling process in the Simio modeling software (Kelton et al., 2013). The model can be confirmed both dynamically and vividly. Part of the screen image for the simulation model is shown in Figure 6.4.

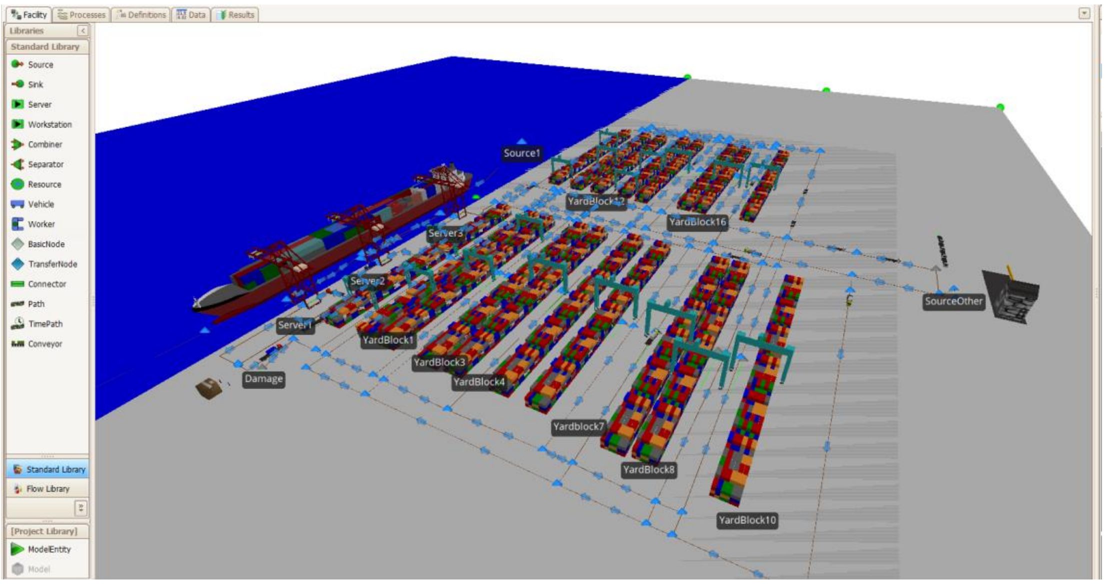


Figure 6.4: Screen snapshot of the simulation model

6.2.5 Experiments and Analysis

In this section, simulation experiments are described to examine the numbers of trailers allocated at the associated container terminal. Although the trailers are relatively low-cost resources in the container terminal, making full use of them is an important issue.

The experiment aims to verify whether system efficiency can be improved by increasing trailer flexibility. Recently, four trailers usually only served one GC that was assigned to ship operation. Therefore, increasing the flexibility of trailers is expected to improve the efficiency of ship operation. A series of scenarios, which are called the to-be model, are shown in Table 6.2. Sets 1, 2, and 3 refer to the trailers in the set that can only serve the corresponding GC. Obviously, in the as-is model, the number of trailers in Sets 1, 2, and 3 are four units. The trailers in Set 4 refer to free trailers, which can serve any of the GC when a job requires a trailer.

In the ship handling operation, the designated number of containers that must be unloaded and loaded by each GC is usually different. In the experiment, the unloading job number of GC1, GC3 varied 5% at each time adjustment. Table 6.3 shows the GCs' workload allocation ratio under the three experimental conditions.

Table 6.2: Data of scenarios

Scenarios	Number of Trailers in Set 1	Number of Trailers in Set 2	Number of Trailers in Set 3	Number of Trailers in Set 4
As-Is Model	4	4	4	0
To-Be Model 1	3	3	3	3
To-Be Model 2	2	2	2	6
To-Be Model 3	1	1	1	9
To-Be Model 4	0	0	0	12

Table 6.3: The GC workload ratio under the different experimental conditions

Conditions	GC1 workload	GC2 workload	GC3 workload
Condition 1	33.33%	33.34%	33.33%
Condition 2	38.33%	33.34%	28.33%
Condition 3	43.33%	33.34%	23.33%

Simulation experiments of the corresponding to-be models are executed with 20 replications, and a 95% confidence interval for the average ship handling time is obtained, as shown in Figure 6.5. The results on the associated scenarios are compared by the container handled number.

From the result obtained by executing the simulation, it is found that the scenario of to-be model 4 is the most efficient of all scenarios under the condition 1. The scenario of to-be model 1 performs best under condition 2, whereas the scenario of to-be model 3 performs best under condition 3.

The results show that balancing the ship's workload during ship handling is one way to increase the GC's productivity, and strategy of flexibly allocating vehicles can be performed effectively in the experiment. Increasing trailers' flexibility in shipping operations is a potential method of improving port operation efficiency using existing resources.

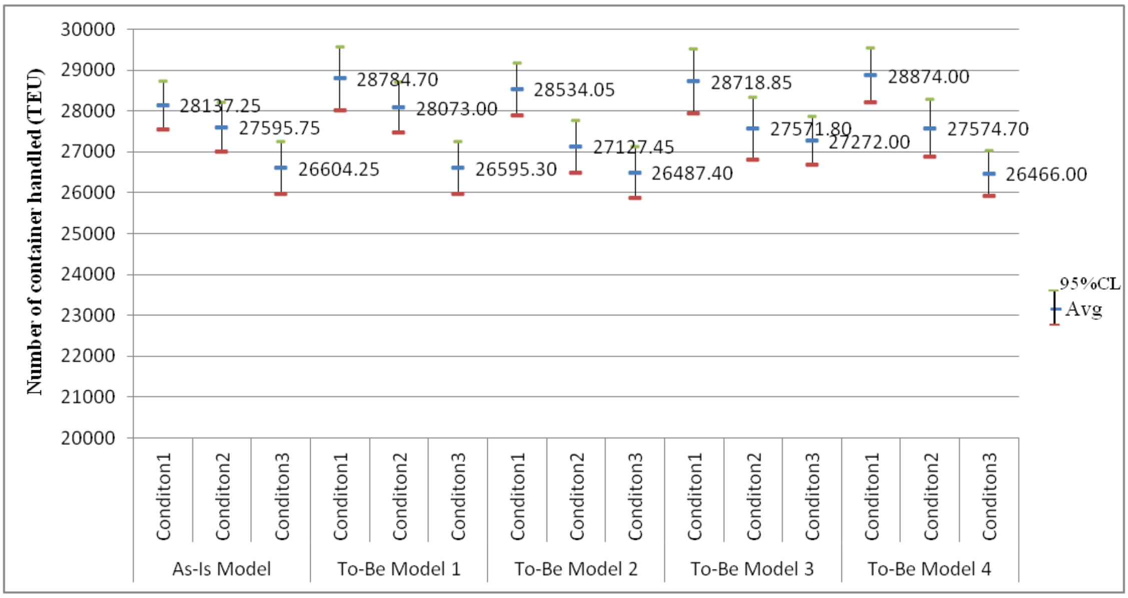


Figure 6.5: Results of the scenarios under the three conditions

6.3 Summary

The simulation model was built using the object-oriented simulation technique and can be applied to analyzing the performance of a container terminal. In this chapter, an object-oriented simulation model of the ship-handling processes is constructed to perform simulation experiment. The study analyzes a proposed solution to the vehicle dispatch problem that aims to dispatch a limited number of trailers that serve GCs to transfer loading/discharging containers from/to the yard for ship operation at quayside. After comparing the number of containers handled under various dispatch scenarios for the trailers that serve GCs in the context of the different workloads represented by these scenarios, it is found that increasing trailers’ flexibility in shipping operations is a potential method for improving ports’ operation efficiency by using existing resources.

7 CONCLUSIONS

7.1 Conclusions

A seaport terminal can be regarded as an organization that creates services from the operations-management perspective by generating and utilizing the inputs handled, which include the berth, the yard, the gate, the cargo-handling equipment, the staff, information, and other resources. The administrative and the operational functions of the seaport terminal provide services that support ocean-vessel transportation and handle import/export cargo via temporary stocking with permission of the government. The dramatic increase in the volume of international trade has compelled seaport terminals to accelerate their administrative processing speeds, enhancing cargo-handling efficiency and reducing operational costs to improve competitiveness in the global logistics environment. Import-cargo lead time during customs clearance and cargo-handling time in the port are important indicates the need to evaluate seaport efficiency. Consequently, this dissertation explored how to organize and generate resources (inputs) to make operations both effective and efficient via information and communication technology (ICT) system support in the seaport terminal.

The dissertation was structured in seven chapters. Chapter 1 presented a brief introduction for overall dissertation, which includes the background of and motivation for the research. Furthermore, three objectives of the study were submitted. *The first objective* is to clarify the effect of the application of ICT on both customs clearance and terminal operational control. *The second objective* is to find a method to analyze and generate data based on the record of a terminal operating system. *The third objective* is to design and evaluate a cargo-handling equipment allocation problem in a container terminal.

To achieve these objectives, chapter 2 presents a general overview of the main issues related to terminal planning and control and illustrates the method used in this dissertation, i.e., the discrete-event simulation. Steps for building the simulation model were introduced. Furthermore, the types of simulation modeling developed for the seaport terminal were clarified.

Next, based on the system operation characteristics, research objectives, and control issues presented in chapter 2, chapter 3 reviews the literature relevant to terminal design, cargo-equipment allocation and optimization, specifically with respect to adopting a simulation modeling and analyzing method. Furthermore, literature on the application of ICT to the seaport terminal and other logistics systems for operational analysis is surveyed.

Next, chapter 4 presents the ICT application in the context of the seaport terminal. The primary purpose of using ICT systems for maritime operations management is to give management a total picture of what is happening as it happens, which at one time could not be properly completed due to the vast complexity of maritime operations management. Two main types of ICT systems used in the seaport terminal are studied: (1) the electronic customs-clearance system; and (2) the terminal operating system. Both systems are utilized to support control and management operations/processes at a seaport terminal to facilitate international trade. The customs-clearance system is used to manage legal documents, provide support, and realize the ability to quickly submit and process documents at the seaport terminal. Systems development and upgrades embrace the trend of integrating the overall authority responsible for customs-clearance processes. In the case of Japan, the time spent on the customs-clearance processing of import cargos was shortened significantly by implementing a single-window system. That said, following a brief description of the material handling flow of the terminal's international trade cargo, a terminal operating system is investigated and both the system control processes and the details of the system tracking data are presented. Supported by the terminal operating system, the cargo and handling-equipment information at the terminal is both visible and controllable, rendering it easy to operate and easy for the staff to arrange to improve operational efficiency. Consequently, this chapter is also studied to achieve *Objective One*.

Chapter 5 develops a VBA program for analyzing and processing the data extracted from the ICT system. Considerable data were recorded in the system, and it is important to extract useful data from large, redundant datasets. The operation data for each piece of container-handling equipment can be sorted sequentially. The yard operation data recorded in the terminal operating system is processed using a developed VBA program. The processed data are used both to capture the system's working features and to obtain the simulation input parameters. Next, a simulation model for the container terminal's ship discharging process is constructed and a special-purpose data generator is developed that can create experimental data to examine the processed data. Furthermore, the flows of the import containers under the various activity levels were examined by executing the simulation experiments. Additionally, a simulation model is developed by applying the generated data to validating the processed data and analyzing handling systems. This chapter is also studied to achieve *Objective Two*.

Chapter 6 uses a simulation model to conduct a performance analysis of a terminal. Container terminals are required to increase their processing speed and reduce their ship dwelling time to meet customers' requirements. In this chapter, an object-oriented simulation model of the ship-handling processes is constructed to perform simulation experiments. The study analyzes a proposed solution to the vehicle dispatch problem that aims to dispatch a limited number of trailers that serve GCs to transfer loading/discharging containers from/to the yard for ship operation at quayside. After comparing the number of containers handled under various dispatch scenarios for the trailers that serve GCs pursuant to those scenarios' different workloads, it is found that increasing the flexibility of trailers in shipping operations is a potential method of improving the efficiency of port operation using existing resources. This chapter is also studied to achieve the *Objective Three*.

Finally, in this chapter, the conclusions are presented, along with a summary and suggestions for further research.

7.2 Suggestions for Future Research

The suggestions of the future research are mainly including:

The study of the lead time for clearing import cargo investigates the statistics obtained from the survey results. If the real submitting and processing time data can be obtained, the customs-clearances processes in the terminal can also be conducted using the simulation method. The proposal to adjust the authority's staff and operating schedules to reduce the time for processing can be expected to be analyzed.

A simulation model with the ship handling processes in the container terminal is developed. The cargo-stocking position in the yard is denoted by the block number, but the model does not contain precise coordinates because it does not affect the distance and time of trailer travel. In addition, the yard crane's processing time is adjusted to increase average transfer time per operation (according to statistics). To improve the model, one could consider marking the precise coordinates of the slot. Then, the efficiency and allocation of the yard crane can be further studied.

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