Simulation-Based Analysis of Container Operations on a Terminal

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ABSTRACT: The progress of information technology has enabled tracking containers at ports. The resulting large, complex datasets must be effectively utilized to help mid- or high-level managers make decisions. This study analyzed real-time tracking data from a container terminal at the Port of Nagoya, Japan. A handling operation model for a ship is constructed and provides insight into the operational performance of the terminal.

KEYWORDS: Container Terminal, Cargo Handling Operation, Data Analysis, System Simulation

1 Introduction

Container terminals play an important role in the economic development of countries due to the rapid increase in international trade. However, due to the scarcity of resources (berths, handling equipment, yard space) and limited operation time, the scheduling of cargo handling operations presents a complex problem. Information technology such as RFID (Radio Frequency Identification) and GPS (Global Positioning System) fulfill a wide range of applications in container terminals and enable tracking of containers. These records are generally used in short-term planning. However, medium-term planning (such as changing the yard layout, updating equipment and reserving personnel) and long-term planning (such as construction of new piers or new berths) require analysis of tracking data over a long period. The real-time data sets are large and redundant, making them difficult to integrate. Thus, managers require the development of an intelligent decision-making tool that utilizes accumulated real-time tracking data. (Liu and Takakuwa, 2011)

Recent simulation studies of container terminals primarily focus on a single critical point within modern container terminals (Legato and Trunfio, 2007), such as i) the arrival of a ship (Asperen et al., 2003), ii) unloading and loading of the ship, iii) transport of containers from the ship to the stack and vice versa (Legato et al., 2008), iv) stacking of the containers (Asperen and Dekker, 2010), and v) inter-terminal transport and other modes of transportation (Sgouridis and Angelides,2002; Guo et al., 2008). However, few studies have addressed the entire operation of a ship using real-time tracking data, which provide a dynamic description of the situation. In this study, the author constructed a handling process model of a ship using real-time tracking data, which represents the first step towards modeling the entire operation of a container terminal.

This paper is organized as follows: Section Two provides a brief description of the Nabeta Pier Container Terminal at the Port of Nagoya. Section Three introduces the operations within the terminal and performs an initial data analysis based on real-time

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tracking data. In Section Four, the cargo-handling process of a ship is simulated using real data, which can provide insight into the operational performance. Conclusions and possible future work are summarized in Section Five.

2 Nabeta Pier Container Terminal at Port of Nagoya

(1) General Description

Nabeta Pier Container Terminal is the largest terminal at the Port of Nagoya. (Port of Nagoya, URL) Foreign trade cargo from China and Korea represents a large proportion of the incoming cargo. Imports of clothing and exports of auto parts and industrial products are the primary cargo transported through the pier. Therefore, there is a large volume of regular weekly service.

Until 1st, Apr, 2012, there were two berths (T1/T2) in Nabeta Pier (Nagoya Port News, URL), which are the objects of this study. The facility layout of the Nabeta Pier Container Terminal is presented in Figure 1. The yard is divided into the transfer crane area and the straddle carrier area. The capacity of the pier is presented in Table 1.

The handling equipment employed at Nabeta Pier includes gantry cranes (GC), transfer cranes (TC), straddle carriers (SC) (Figure 2) and trailers. Top lifters at Nabeta Pier are primarily used to deal with empty containers (there is also a vanpool yard outside of the container yard gate) before they are carried into the container yard. Thus, top lifters are not among the objects of this study.

Table 1 Capacity of Nabeta Pier

Berth No.	T1/T2
Berth Length (m)	735
Depth (m)	14
Box Capacity (TEU)	20,784
Terminal Area (m^2)	416,426
Reefer Plugs	296
Gantry Cranes	6
Transfer Cranes	24
Straddle Carriers	3
Crane Outreach	17/18 rows
Throughput (TEU)	815,690

(Source: Port of Nagoya, URL)

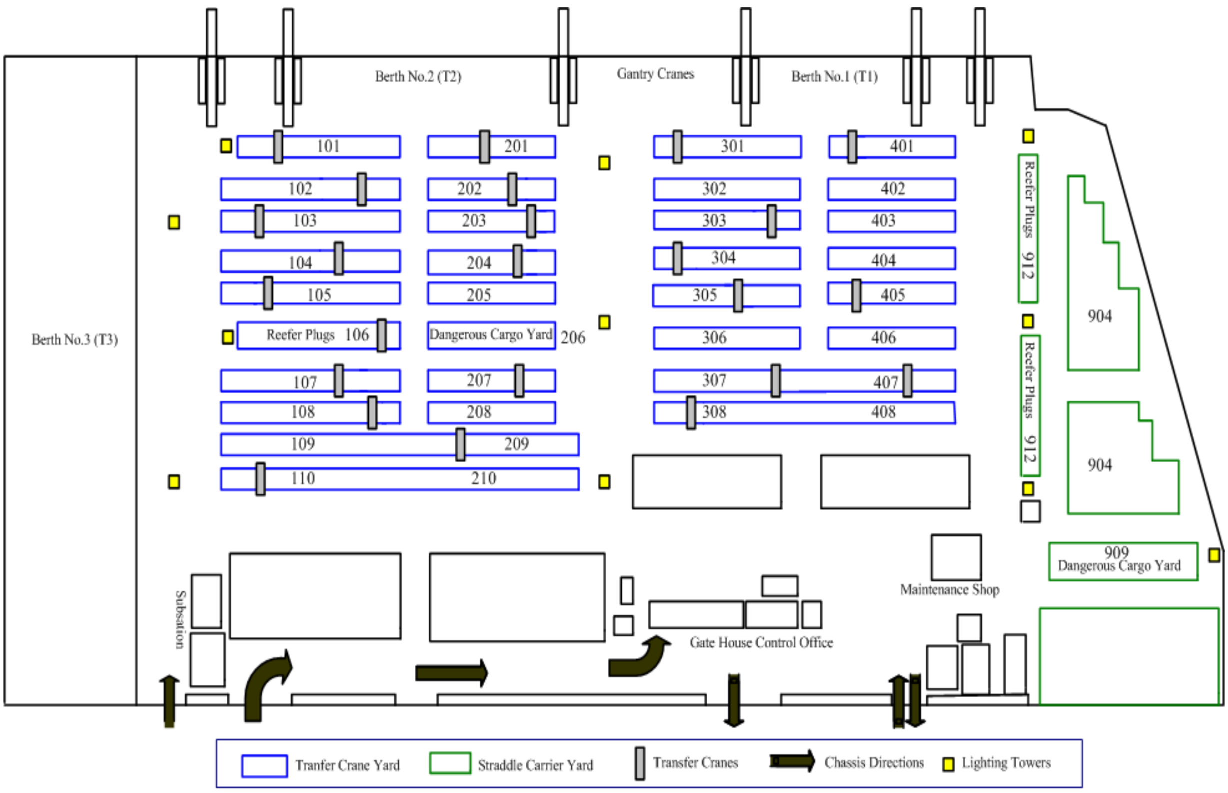


Figure 1 Facility Layout of the Nabeta Pier Container Terminal

(a)Gantry Crane

(b) Transfer Crane

(c) Straddle Carrier

Figure 2 Handling Equipment at Nabeta Pier (Nagoya Port Terminal Pubic Corporation, URL)

(2) The information system NUCT

NUCT is short for Nagoya United Terminal System, which is used as the information platform for all container terminals in Nagoya. (NUTS, URL) NUTS includes four sub-systems: yard planning, yard operation, control and vessel planning. All terminals of the Port of Nagoya are connected by LAN or WAN lines so that system monitoring and maintenance can be performed from a single location. The movement of containers is recorded in real-time by the NUCT system, which generates the real-time tracking data used in this study.

3 Operation process analyses on Nabeta Pier

(1) Operation Process

Port businesses can generally be divided into import businesses and export businesses, and these two categories employ opposite operation flows. Figure 3 presents a general operation process flow chart for import containers.

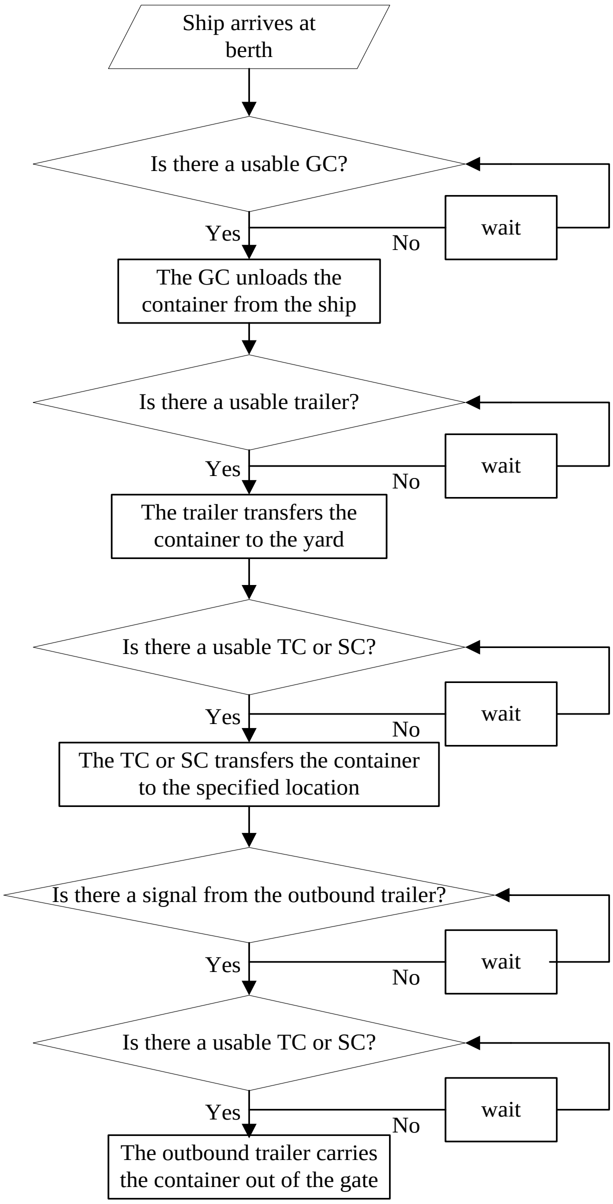


Figure 3 General operation process for an import container

Real-time tracking data concerning the handling processes inside the container yard will be recorded, including necessary data (loading/ unloading to/ from ship or carry-in/ out gate) and redundant data (moving a container to access another container underneath).

(2) Operation Data Analysis

This study utilizes 11 days of real-time tracking data from Nabeta Pier, including data about the ship and the cargo handling process. Some basic statistics will be useful to the simulation.

i) The main parameters of the containers.

There are five types of container used at Nabeta Pier: the Dry Container (DC), the Reefer Container (RC), the Flat Rack Container (FC), the Open Top Container (OT) and the Tank Container (TaC). The DC is the most commonly used container. RCs should be stocked in the reefer plug area. Similarly, TaCs should be stocked in the dangerous cargo area. The parameters of each container type are presented in Tables 2 (a) and (b). The weight of a container can affect the handling sequence.

Table 2 Parameters of the containers

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

(a) Relative proportions of containers of each type and size

ii) The main parameters describing ship handling

Combining data about the ship and the yard containers, we can obtain a set of parameters describing the ship handling. The number of ships arriving during each day of the data period is presented in Figure 4, as well as the quantity of containers unloaded (UL) /loaded (LD) to/from the ships each day. The 7th day in the period was a weekend, but overtime operations continued. In addition, a Typhoon Warning was issued on the 12th day, which explains the decrease in operational volume on the 11th day. The data from these two days can be removed or used as failure data.

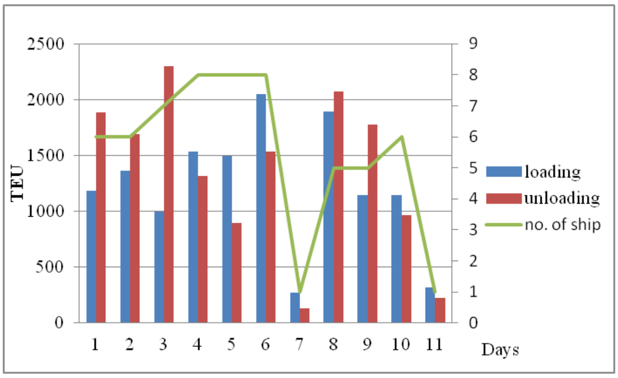


Figure 4 Number of containers Unloaded/loaded containers from/to ships and the number of ships arriving each day

When a ship arrives at the port, it takes time to dock the ship at the pier and prepare it for handling (HandlingStart-ShipArrival). After the handling process is finished, it also takes time for the ship to depart (Depature-HandlingEnd). An additional delay is necessary but not productive, and the port management aims to shorten the delay time. The ships' handling times and delay times at the berth are

		20'	40'
Export	DC	2130 + 28000 * BETA(0.964, 1.51)	3190 + 28800 * BETA(1.35, 1.5)
	RC	2820 + 13900 * BETA(0.415, 1.06)	3670 + 25000 * BETA(0.794, 0.826)
	TaC	3000 + 26200 * BETA(0.37, 0.469)	
	Other	2200 + 22900 * BETA(0.731, 1.36)	3800 + 30500 * BETA(1.4, 1.34)
Import	DC	2100 + 28400 * BETA(0.89, 1.33)	3600 + 44200 * BETA(1.32, 4.44)
	RC	2200 + 22700 * BETA(1.53, 1.38)	3700 + 28900 * BETA(1.52, 0.849)
	TaC	2200 + 26800 * BETA(0.676, 0.405)	
	Other	2000 + 20500 * BETA(0.474, 0.505)	3800 + 42800 * BETA(0.358, 1.1)

(b) Weight (kg) of each type and size of container presented in Figure 5, which demonstrates that delay time occupies approximately 30% of the total time at Nabeta Pier. In addition, the parameters of the 3 described phases are presented in Table 3.

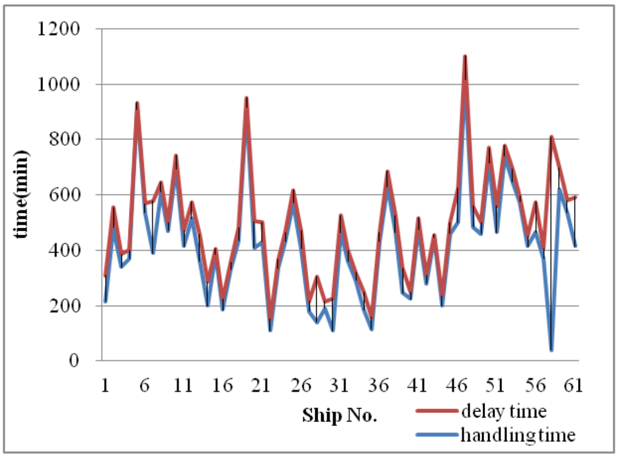


Figure 5 Cargo handling times and delay times at the berth

Table 3 Ship handling times and delay time at the berth

Process	Time
HandlingStart-ShipArrival	5 + EXPO(33.2)
Handling Process Time	NORM(423, 198)
Depature-HandlingEnd	5 + EXPO(27)

Due to the high cost of docking, ships have priority over other handling equipment. A container prepared for loading onto a ship or unloading from a ship is stocked in the yard for a period of time. The inventory time is presented in Table 4. The proportions of the different operation numbers in each area of the yard are shown in Figure 6; the green line indicates the cumulative ratio.

Table 4 Container inventory time in the yard

Type	Inventory Time
Export	-0.5 + LOGN (3.15, 2.29)
Import	-0.5 + LOGN(5.89, 5.55)

These parameters can be derived from the real-time tracking data and used by the simulation. The method for including the time used by handling equipment (TC,SC) will be introduced in the next section.

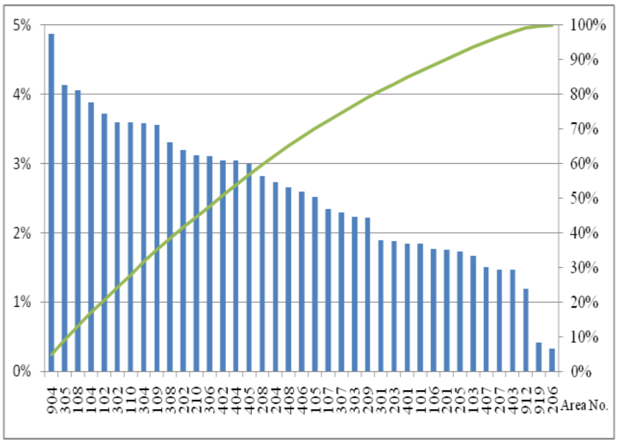


Figure 6 Proportion of the various operation numbers in each area of the yard

4 Simulation Analyses

(1) Case Study: One ship

A handling process model of a ship using real-time tracking data is constructed in this study. A ship that arrived during the 4th day of the data period was chosen for a detailed study of the entire operations process. A set of basic information is presented in Table 5. The total residence time of the ship was 464 min, 430 min of which was cargo handling time.

Table 5 Basic information regarding the ship under study

The ship Number	No. 24
Ship Arrival Time	16:06
Handling Start Time	16:30
Handling End Time	23:40
Ship Leave Time	23:50
Number of import container	191
Number of export container	125

The essential handling processes for a single ship can be described using the flow chart shown in Figure 7. The export containers were carried into the yard between 10 days and 1 day before the ship arrived. The import containers were carried out sequentially the day after the ship's arrival.

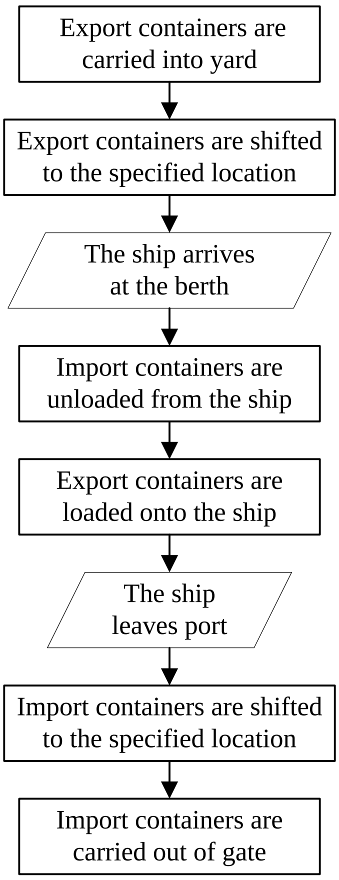


Figure 7 The essential ship handling processes

(2) Data Selection

Tracking data for all of the containers corresponding to this ship were extracted. Each container's attributes (No., Size, Type and Weight) were recorded. Through the unique container ID, the entire dataset describing the ship's container handling processes can be obtained and used to build the model.

The real-time tracking data only contains the handling reservation time and the completion time recorded by the handling equipment. The operation records of each piece of handling equipment are sorted sequentially. The i^{th} operation's handling start time can be calculated as:

Set

Handling starting time to t_s

Handling reservation time to t_r

Handling completed time to t_c

If $t_r i < t_c(i-1)$, then $t_s i = t_c(i-1)$

If $t_r i > t_c(i-1)$, then $t_s i = t_r i$

An example of the input data is presented in Table 6.

(3) Results

The simulation model provides the handling waiting time and the time (average, min, max) the equipment requires to unload a container. The results are presented in Figure 8.

These results highlight the bottleneck of the operation. In this case, the operating time and waiting time of SC20 are much longer than those of the other equipment. Thus, long-term real-time tracking data can uncover operational bottlenecks, which provide a basis

Table 6 Example of the input data

No.	Handlng Completed Time	Handlng Reservation Time	Handlng Starting Time	Operation Type	Ship No.	Gantry No.
i-1	18:35:29	18:29:17	18:33:12	UL	No. 24	V2
i	18:37:13	18:30:56	18:35:29	UL	No. 24	V2
i+1	18:40:53	18:32:56	18:37:13	UL	No. 24	V2

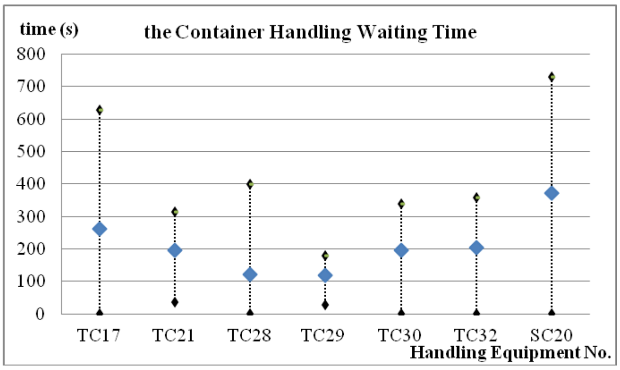
(1)

Container No.	Size	Type	Container Weight	Handling Equipment No.	Operation Area No.	Unloading Time	Truck ID
TTNU5984088	40	DC	24800	TC28	402	18:28:47	DX004
TSLU0408748	40	DC	24100	TC28	402	18:30:27	KR068
FCIU3999481	20	DC	2900	TC28	402	18:32:27	CK353

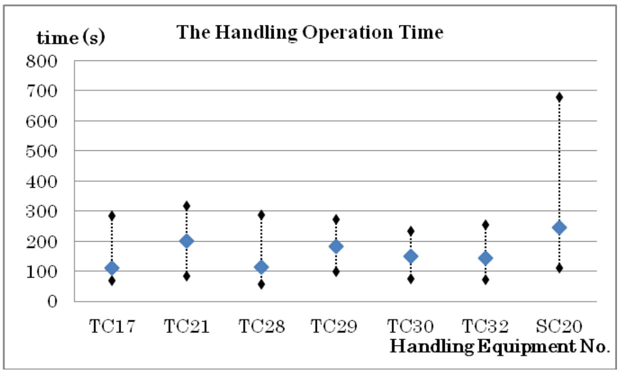
(2)

for improving the terminal's design.

Figure 8 The output of the model



(1) The waiting time before the container can be unloaded



(2) The time taken to unload the container

5 Conclusions

Analysis of tracking data for ships and cargo handling processes in a container terminal in Japan is described in this study. A model for the ship handling processes was constructed using real-time tracking data and can be extended to further large-scale simulations. The model could provide a more realistic reflection of the actual situation using real-time data, which can be used to comprehensively evaluate the port's operational status. This tool is expected to be useful in mid-term planning or in planning of a new container terminal.

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