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# MODELING THE MATERIALS HANDLING IN A CONTAINER TERMINAL USING ELECTRONIC REAL-TIME TRACKING DATA

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## ABSTRACT

Information systems have been introduced to accumulate real-time tracking data on containers and transporters at container terminals in ports. Logistics managers of container terminals need an intelligent tool to analyze the performance of highly complex and large logistics systems using the accumulated real-time tracking data. In this paper, all of the operational activities of an actual container terminal in Japan are simulated to analyze the processing time and the bottlenecks of the operations flows. The method for collecting the required data for performing simulation is described, especially by making use of electronic real-time tracking data that is accumulated from the information systems. The procedure is applied to an actual container terminal in a port. It is found that the information obtained by performing simulation is effective for analyzing the performance of the operation.

## 1 INTRODUCTION

Marine container terminals play an important role in worldwide supply chains; container terminal operation systems are complex and large and are designed to provide customers with high-quality service. Information technology including GPS (Global Positioning System) and RFID (Radio Frequency Identification), provides an impetus for the control-support information systems to accumulate real-time tracking data of containers and cargo-handling equipment in the container logistics terminals. There is a potential need for logistics managers to have an intelligent tool, which should be developed to analyze these highly complex and dynamic logistics systems, making use of accumulated real-time tracking data.

There are many studies focused on various issues concerned with container terminals. Several studies have used computer simulation to schedule cargo-handling equipment including yard cranes, quay cranes, and terminal transporters at container terminals (Kim and Kim 1999; Ng 2005; Guo et al. 2008). The issues of storage and stacking in the planning of ships and container yards can be addressed using simulation, which has been studied in recent years (Asperen and Borgman 2010; Dekker, Vooogd, and van Asperen 2006; Duinkerken, Ever, and Ottjes 2001; Zeng et al., 2010). All of these papers demonstrate that simulation is a tool for evaluating and analyzing materials handling operations for logistics systems. In addition, Vis and Koster (2003) gave a classification for decision problems that arise at container terminals. A current review of the literature indicates that few studies have been reported on the modeling of a whole container terminal system with a simulation based approach using electronic real-time tracking data.

In this paper, a simulation approach is employed at all of the operations of real container terminals in Nagoya, Japan, specifically at the Nabeta Pier container terminal, to analyze the processing time and the bottleneck of operation flows. The method for collecting the required data for all of the operations is described, especially the use of electronic real-time tracking data accumulated from the control-support information systems. Simulation based on real-time tracking information is developed and applied to analyze the performance at a typical real container terminal.

## 2 NABETA PIER CONTAINER TERMINAL

The Nabeta Pier Container Terminal in this study sustains the central Japan economic arena with a focus on multi-frequency small-sum cargo. This terminal started full-fledged operations in April 2001 utilizing two consecutive berths as one. The main types of cargo that are handled are export cargo (e.g., transportation machinery, steel, and general machinery), import cargo (e.g., raw materials for feed, rice, and fiber products) and transshipment (domestic) cargo (e.g., steel materials, raw materials for the ceramic industry, and electrical household appliances). The terminal handles mainly Chinese and Korean cargo, and its handling volume accounts for approximately one third of the handling volume at the Port of Nagoya. A general view of the Nabeta pier container terminal is shown in Figure 1.

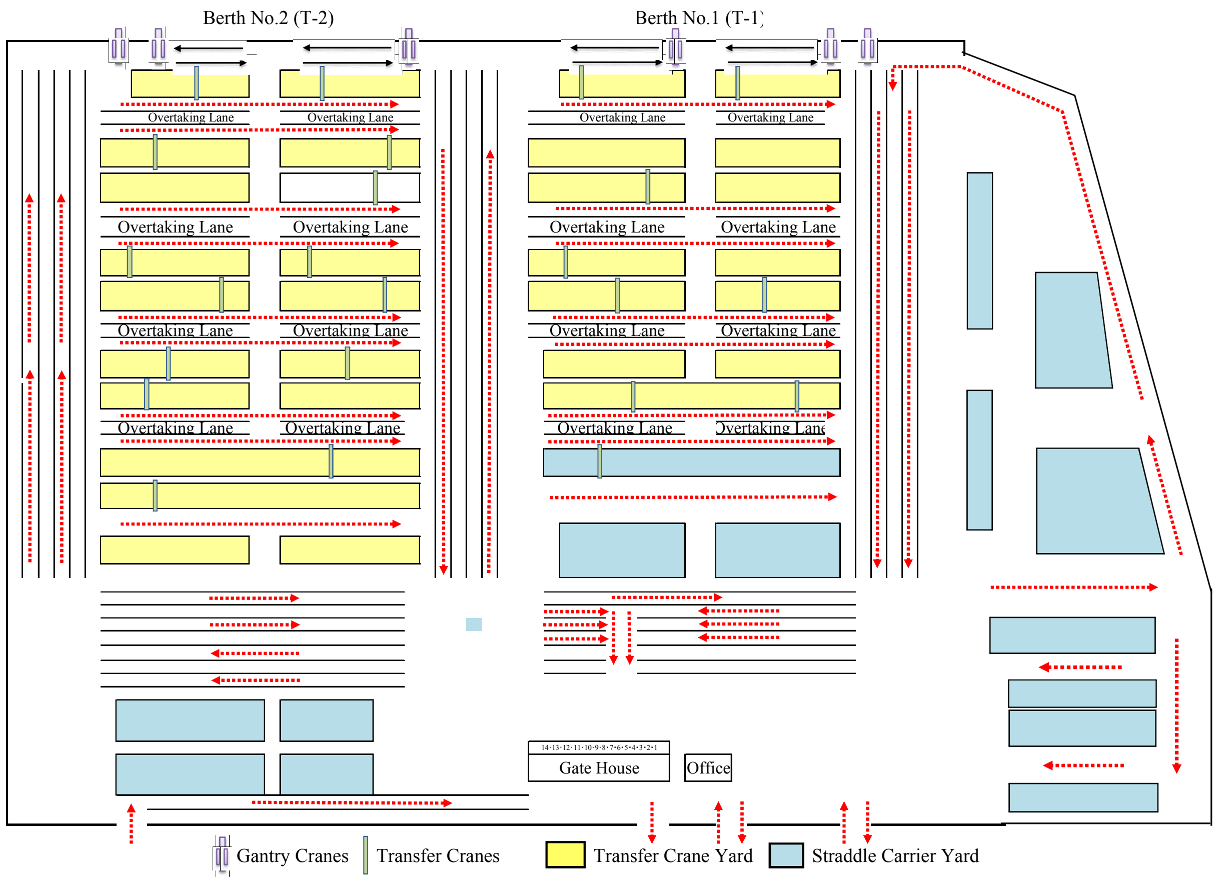


Figure 1: Overview of the facility layout of the Nabeta Pier Container Terminal

Responding to the increasing amounts of container cargoes, the efficiency of materials handling operations are becoming a vital problem. Although advanced information systems, together with GPS and RFID technologies, have contributed to tracking the locations of containers and cargo-handling equipment's to make operation control easier than before, it is still difficult for logistics managers to resolve the problem of ship inbound and outbound delays which can only be accomplished with real-time tracking data. Logistics managers need a sophisticated tool to integrate the electronics real-time tracking data with an advanced information system to analyze the bottleneck of operation flows, the processing time of different cargo-handling equipment and the average waiting time of the inbound and outbound ships.

## 3 ELECTRONIC REAL-TIME TRACKING DATA OBTAINED BY NUTS

The Nagoya United Terminal System (NUTS) is a computer-aided information system used for planning for vessels, cargo-handling equipment and yard storage planning. Figure 2 shows the flow for the container operations and the data flows via NUTS. When a ship berths at the container terminal, a container is discharged by a quay crane and is unloaded onto an inside tractor that is waiting to transfer material to the yard storage blocks. Once the container is unloaded onto the bed of the tractor, the information on the loading completion will be transferred to NUTS. Nearly at the same time, handling instruction for containers-storage spots will be sent to cargo-handling equipment at the yard, including transfer cranes, straddle careers, and top lifters. It is possible to send this information to the next job in advance of the actual tractor arrival. In addition, it is valuable for the cargo-handling equipment at the yard to choose the next job in helping to make the proper decisions. In the meantime, NUTS will record the exact time when instructions are sent out as well as the time that handling completion information is accepted.

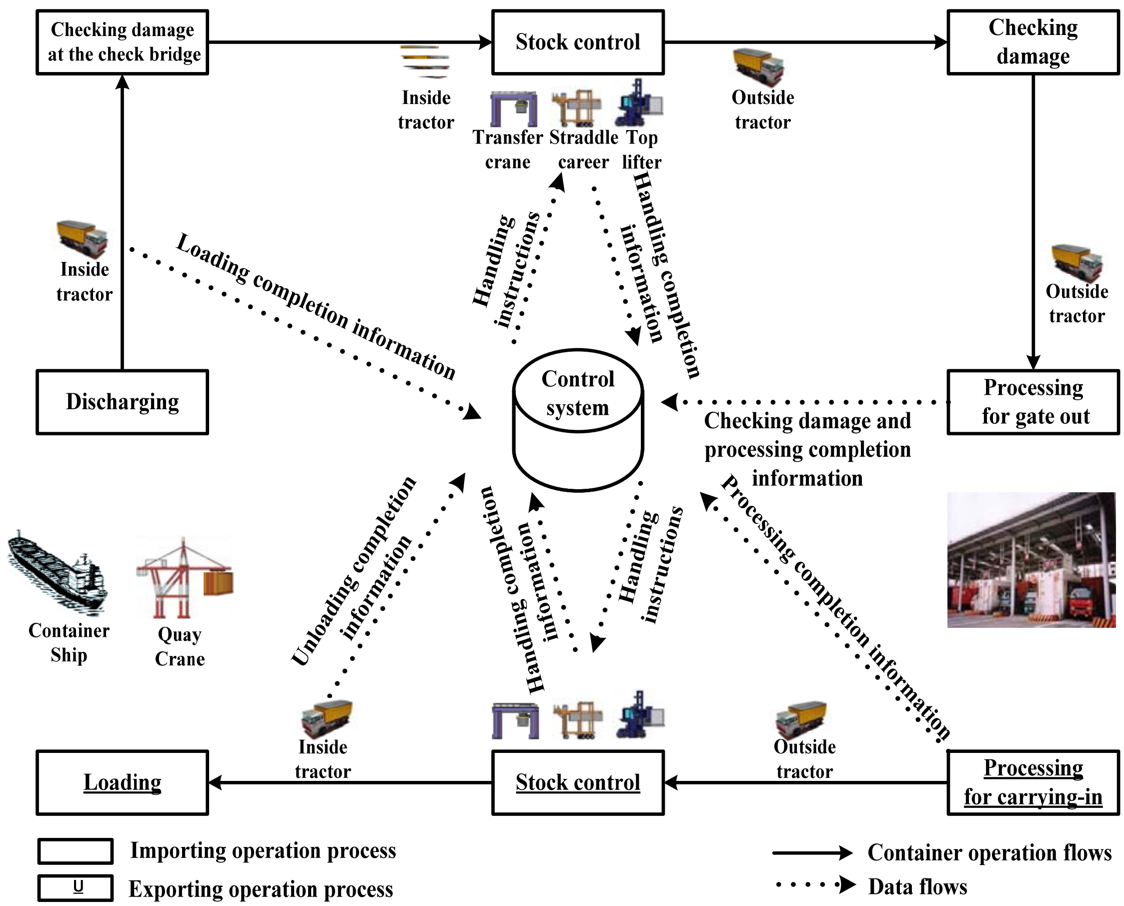


Figure 2: Container operation flows and data flows in NUTS

To shorten the docking time of the vessels to be as short as possible, a third new berth is being constructed which will increase the yard capacity from 18,556 TEU (twenty feet equivalent unit container) to 20,784 TEU. Actual operational activities are so dynamic that the cargo-handling equipment are mutually dependent on one another. Hence, the data on the current container terminal are expected to be used to evaluate the performance at the new berth in this study.

## 4 ESSENTIAL MATERIALS HANDLING PROCESSES IN A CONTAINER TERMINAL

The fundamental operation processes in a typical terminal including importing and exporting processes are shown in Figure 3. The importing process means that an inbound container is discharged from an inbound vessel by a quay crane and is unloaded onto an inside tractor that transfers material to the yard storage blocks. The exporting process is that an outbound container is loaded onto a tractor by cargo-handling equipment at the yard, such as transfer cranes, straddle careers, and top lifters, and then transferred to an outbound vessel by quay crane. In addition to the fundamental operation processed, there are five indispensable operational activities:

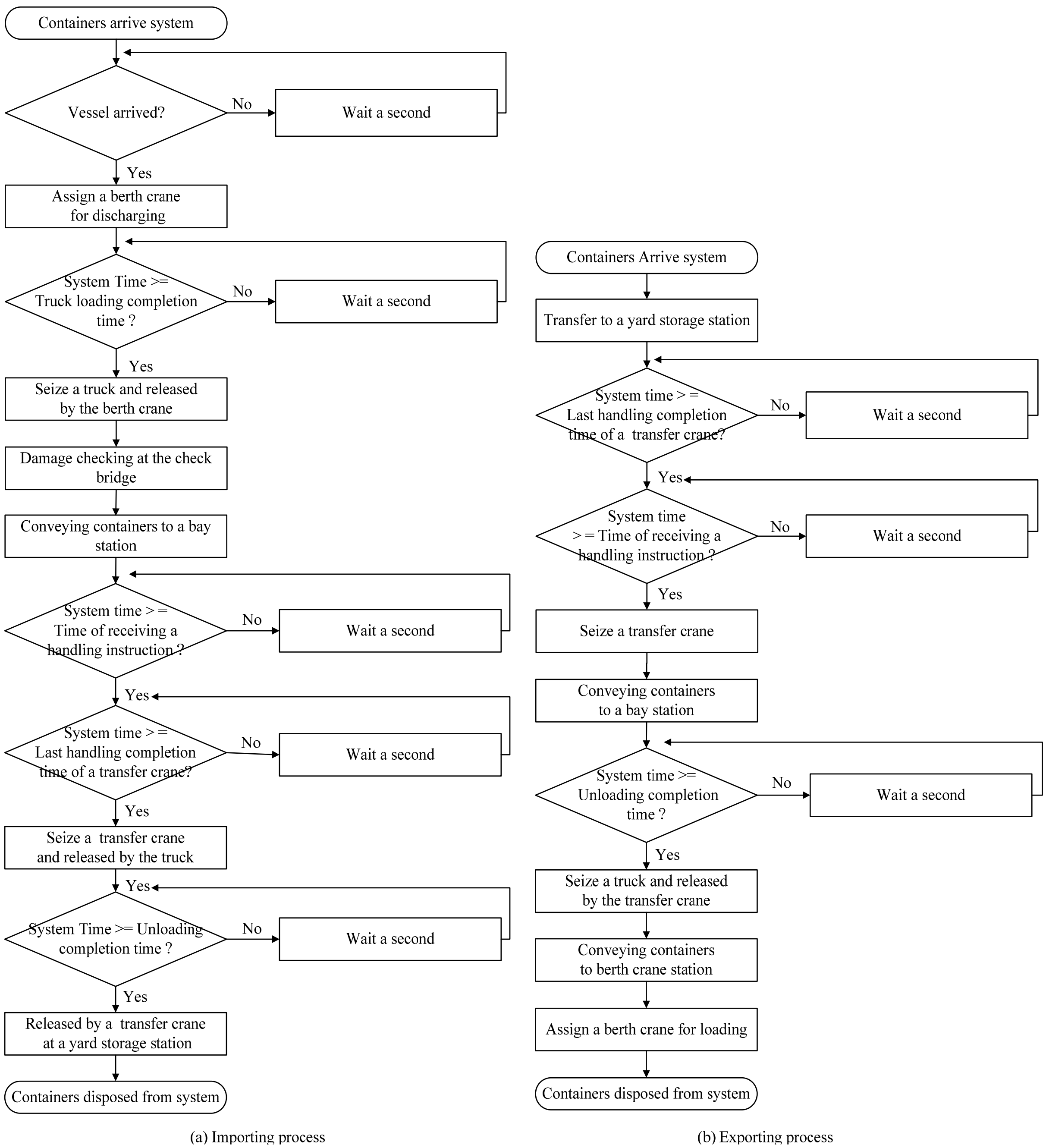


Figure 3: Essential operation processes for a typical terminal

1. Gate-in process from gate to storage yard
2. Gate-out process from storage yard to gates
3. Handling by transfer cranes within the same bay in a block
4. Handling by transfer cranes between the different bays in a block
5. Handling between the different blocks by transfer cranes and a tractor

The overall flow of the data processing in this study is shown in Figure 4, which can be itemized as follows:

- Acquire a series of raw data, including handling instructions and handling completion information for transfer cranes, straddle careers, and top lifters, inbound vessel information called “import_discharged,” and outbound vessel information called “export_load.”
- Process a series of raw data.
- Extract input data for simulation from the processed data based on the operation flows.
- Perform simulation.
- Obtain simulation output.

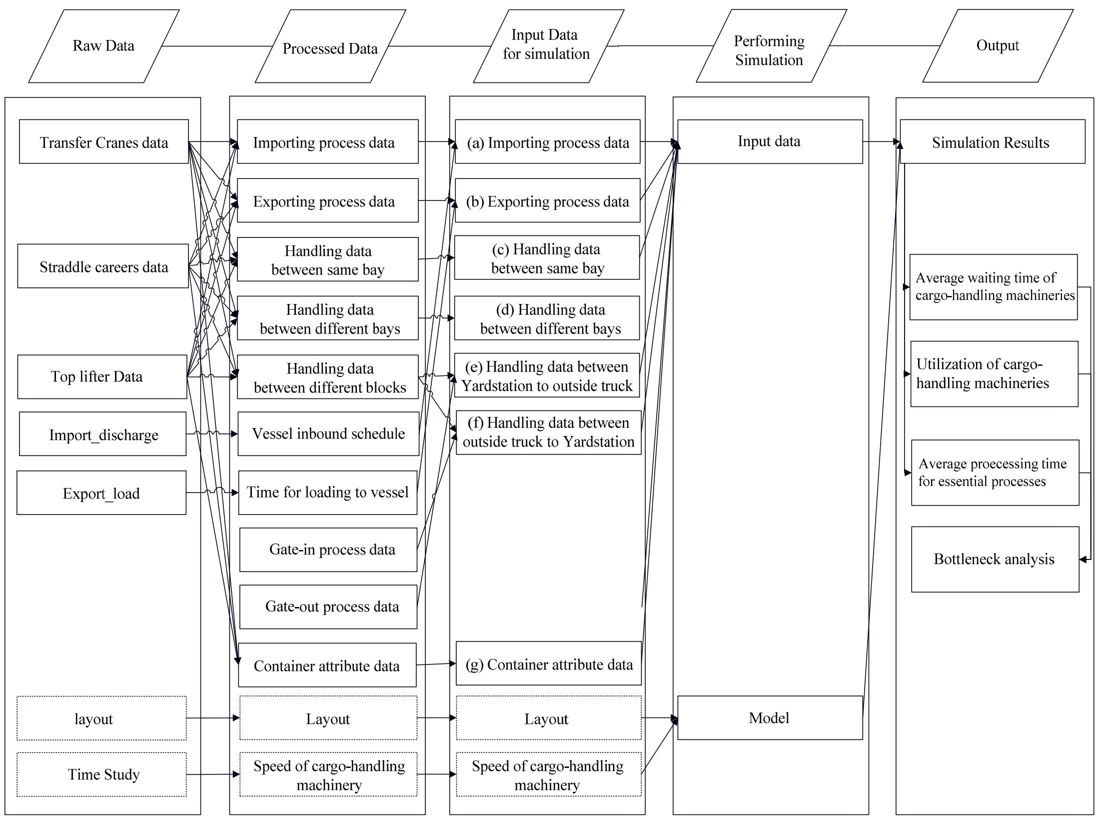


Figure 4: Overall flow of data processing

Selected resultant input data for a real container terminal simulation is summarized in Table 1. The electronic real-time information regarding the operation processes is designed for performing simulations repeatedly and effectively. A similar idea for creating experimental data for simulation experiments appears in the simulation of hospital wards (Takakuwa and Katagiri 2007; Wijewickrama and Takakuwa 2006). Selected resultant input data are shown in Table 1. The simulation can be performed automatically, using a model together with the input data. Therefore, a judicious integration of real-time data into the simulation model will reduce the work load of specification, coding, validation, and verification of the simulation.

Table 1: Selected resultant input data for the simulation of an actual container terminal

(a) Importing process (Operation types: UL and TU)

| No.(Priority No.) | Container No. | Vessel No. | Berth crane No. | Real time of loading completion for a truck | Truck No. | Real time of handling instruction for a cargo-handling machinery |
|---|---|---|---|---|---|---|
| 1 | TRIU8380996 | STNG | 1 | 9.18 | KR024 | 9.06 |
| 2 | NSSU0072627 | HTYO | 4 | 10.71 | TX170 | 10.69 |

| Real Time of last job finished for a cargo-handling machinery | Cargo-handling machinery No. | Block No. | Bay No. | Row No. | Real time of job finished for a cargo-handling machinery |
|---|---|---|---|---|---|
| 9.18 | TC11 | 1F | 15 | 4 | 9.29 |
| 10.62 | TC11 | 2F | 12 | 3 | 10.80 |

(b) Exporting process (Operation types: LD)

| No.(Priority No.) | Container No. | Cargo-handling machinery No. | Block No. | Bay No. | Row No. | Real time of handling instruction for a cargo-handling machinery |
|---|---|---|---|---|---|---|
| 1 | PCSU2120915 | TC18 | 2C | 40 | 5 | 10.98 |
| 2 | PCSU2108036 | TC18 | 2C | 40 | 6 | 11.01 |

| Real Time of last job finished for a cargo-handling machinery | Real time of job finished for a cargo-handling machinery | Truck No. | Berth crane No. | Vessel No. |
|---|---|---|---|---|
| 11.01 | 11.03 | KP118 | V4 | HTYO |
| 11.03 | 11.06 | TK136 | V4 | HTYO |

(c) Handling between the same bay in a block (Operation types: RS and IS)

| No.(Priority No.) | Container No. | Cargo-handling machinery No. | Block No. | Bay No. | Row No.(from) | Row No.(to) |
|---|---|---|---|---|---|---|
| 1 | CRSU6022868 | TC11 | 1F | 17 | 2 | 3 |
| 2 | YMLU7415614 | TC11 | 1F | 10 | 2 | 3 |

| Real time of handling instruction for a cargo-handling machinery | Real Time of last job finished for a cargo-handling machinery | Real time of job finished for a cargo-handling machinery |
|---|---|---|
| 8.80 | 8.80 | 8.87 |
| 9.36 | 9.34 | 9.43 |

(d) Handling between different bays in a block (Operation types: IB)

| No.(Priority No.) | Container No. | Cargo-handling machinery No. | Block No. | Bay No.(from) | Row No.(from) | Bay No.(to) |
|---|---|---|---|---|---|---|
| 1 | CKLU4107919 | TC30 | 3E | 07 | 04 | 04 |
| 2 | PCLU4050914 | TC30 | 3E | 07 | 05 | 04 |

| Row No.(to) | Real time of handling instruction for a cargo-handling machinery | Real Time of last job finished for a cargo-handling machinery | Real time of job finished for a cargo-handling machinery |
|---|---|---|---|
| 05 | 7.57 | 8.32 | 8.36 |
| 04 | 7.57 | 8.36 | 8.40 |

(e) Handling between yard station to outside tractor (Operation types: SO and D)

| No.(Priority No.) | Container No. | Cargo-handling machinery No. | Block No. | Bay No. | Row No. | Real time of handling instruction for a cargo-handling machinery |
|---|---|---|---|---|---|---|
| 1 | KKTU7880852 | TC15 | 1J15051 | 15 | 05 | 8.41 |
| 2 | DFSU2085042 | TC15 | 1J15022 | 15 | 02 | 8.41 |

| Real Time of last job finished for a cargo-handling machinery | Real time of job finished for a cargo-handling machinery |
|---|---|
| 8.63 | 8.67 |
| 8.67 | 8.69 |

(f) Handling between outside tractor to yard station (Operation types: SI and R)

| No.(Priority No.) | Container No. | Cargo-handling machinery No. | Block No. | Bay No. | Row No. | Real time of handling instruction for a cargo-handling machinery |
|---|---|---|---|---|---|---|
| 1 | SNBU2114676 | TC11 | 2F | 33 | 02 | 8.50 |
| 2 | TRIU8666969 | TC26 | 2E | 27 | 01 | 8.51 |

| Real Time of last job finished for a cargo-handling machinery | Real time of job finished for a cargo-handling machinery |
|---|---|
| 8.52 | 8.57 |
| 8.55 | 8.58 |

(g) Container attributes

| Container No. | Size | Type | Height | FE(Full=1/Empty=0) | Weight | Vessel name |
|---|---|---|---|---|---|---|
| PCSU2120915 | 20 | DC | 86 | 1 | 15563 | HTYO |
| CRXU6921757 | 40 | RC | 86 | 1 | 28900 | JID |

The input data for a simulation of an actual container terminal consist of the following: (a) an importing process, (b) an exporting process, (c) handling within the same bay, (d) handling between different bays, (e) handling from the yard station to an outside tractor, (f) handling from an outside tractor to the yard station, and (g) the container attributes. These inputs respond to the essential material handling processes described in Section 4. Simulation with electronic real-time data is valuable for assessing the performance at the container terminal. In this paper, the simulation model is conducted with the Simio modeling software, version 3.48 (Kelton et al. 2010; Pegden and Sturrock 2010). By using Simio modeling software, dynamic 3D animated models of container terminals can be built efficiently. A part of the animation screen is shown in Figure 5.

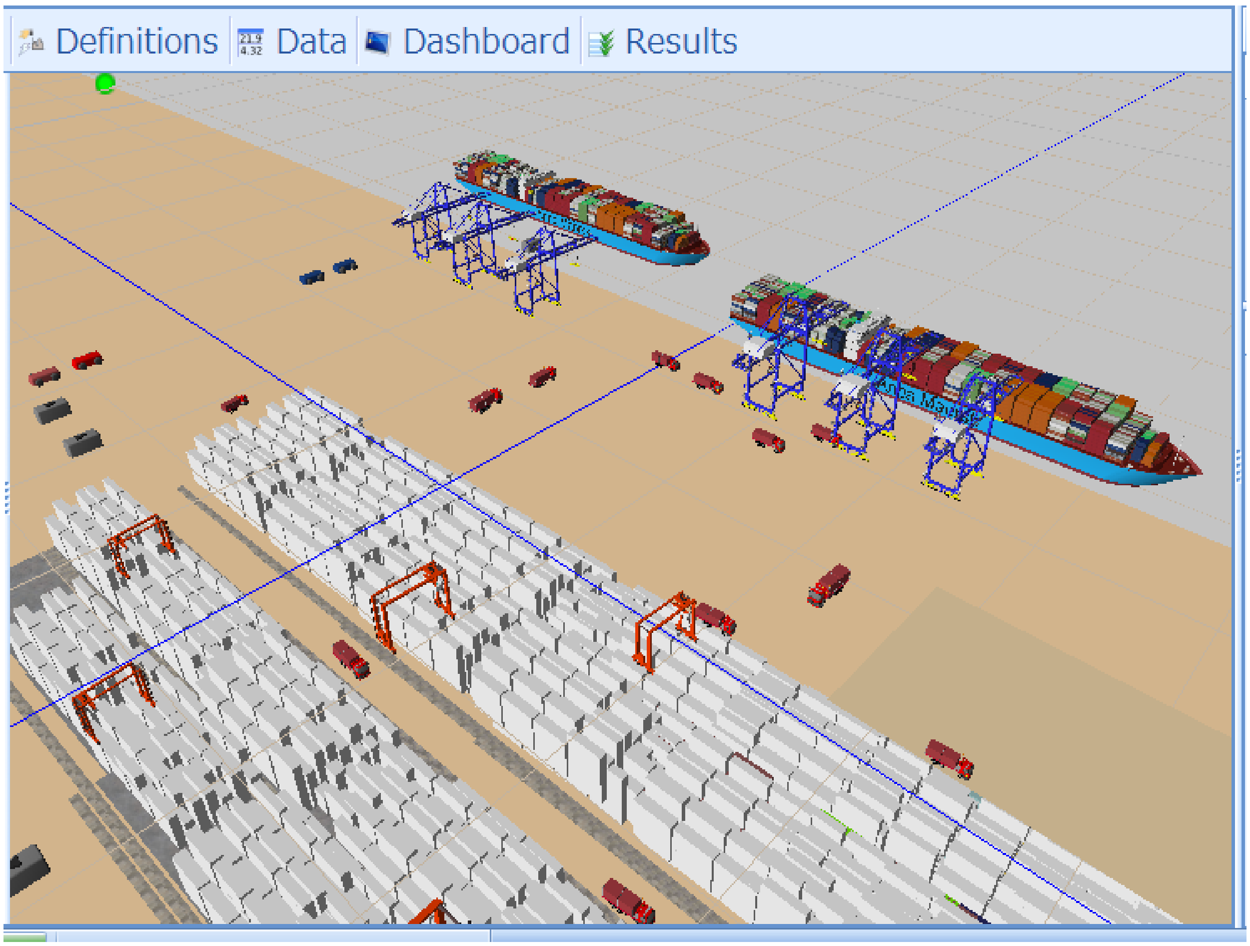


Figure 5: A Part of the Animation Screen

The simulation model can be run to examine the overall operation processes for all of the cargo for the coming day, based on the exact electronic real-time data of the day. By performing the simulation, a number of performance measurement variables can be recorded and output, as follows:

- Average processing time of containers for essential processes, such as the importing process and the exporting process
- Utilization of cargo handling machinery
- Average waiting time of cargo-handling machinery

Based on the simulation results, the planning and the control concepts for different types of materials handling machinery are verified, and the detailed daily bottleneck problems with respect to the operation flows are easily identified. In addition, the simulation results are expected to predict performance indicators such as the productivity, and the average waiting time for cargo-handling equipment, when assessing the effects of the prospective new berth.

## 5 CONCLUSIONS

A simulation approach is proposed, to model an entire operations process at an actual container terminal in Japan. The procedure for collecting the required data for all of the operations is described; this data is used when performing the simulation. Electronic real-time tracking data are extracted from the information systems that control all of the operations for the entire port. The procedure is applied to an actual container terminal in a port. The simulation results can be used to analyze the level of performance for material handling processes, such as the average waiting time and the utilization of cargo-handling equipment. In addition, this approach is expected to be useful for assessing the effects of enhancing the capabilities of a berth in a port.

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