Proceedings of the 2014 Winter Simulation Conference
A. Tolk, S. Y. Diallo, I. O. Ryzhov, L. Yilmaz, S. Buckley, and J. A. Miller, eds.

SIMULATION-BASED FLEXIBILITY ANALYSIS OF VEHICLE DISPATCHING PROBLEM ON A CONTAINER TERMINAL WITH GPS TRACKING DATA

Wenhe Yang
Soemon Takakuwa

Graduate School of Economics and Business Administration
Nagoya University
Furo-cho, Chikusa-ku
Nagoya, Aichi 464-8601, JAPAN

ABSTRACT

To provide better services for shipping companies and to increase profits, improving the operation equipment efficiency and reducing the ship dwelling time at the terminal is an important problem for port companies. Port management information system and information technology is widely used for supporting and controlling the terminal operation, which can track the operation data simultaneously. In this study, a simulation model is constructed using historical Global Positioning System tracking data and analyzed for application to the shipping industry. For improving handling equipment efficiency, flexibility 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. The proposed procedure to construct simulation models of container terminal was found to be both practical and powerful.

1 INTRODUCTION

With the increasing volume of world trade, ports play an important role in international logistics. Contemporary sea transport carries approximately 90% of the world trade volume (Ducruet 2013). Because of advantages that include less packaging, less damage to the goods and improved productivity, the oversea transport of finished consumer goods is currently almost always carried out in containers on deep-sea container ships (Kemme 2013). Container terminals serve as hubs for container temporary stocking from sea to sea or to the hinterland.

Container terminals are required to service the ship in a short time limit because of lack of access to the berth. To provide better services to the shipping companies and to increase profits, improving the container handling equipment operational efficiency and reducing the ship dwelling time at the terminal is an obviously important problem to a port company. The container handling equipment at the container terminals typically includes gantry cranes (GC); yard cranes, such as transfer cranes (TC) or straddle carriers (SC); and vehicles (inside and outside). These types of equipment can be used in different combinations (Sgouridis and Angelides 2002). To easily distinguish the vehicles, the inside vehicles are denoted as trailers and the outside vehicles are denoted as trucks in this study.

978-1-4799-7486-3/14/$31.00 ©2014 IEEE

A port management information system is currently widely used in the container terminal for controlling the container status, yard stock, quay scheduling, and container handling equipment operation. Information technology, including Global Positioning System (GPS) and Radio Frequency Identification (RFID), provides an impetus for the control-support information systems to accumulate real-time tracking data of the containers and container handling equipment in the container terminals (Liu and Takakuwa 2011). With a unique container identification number (No.), a useful dataset can be extracted from a large number of redundant data. The container handling processes are clarified and the input data for the simulation can be generated from the dataset.

In this study, a container terminal with a TC yard in Nagoya, Japan, is investigated. After a brief literature review, the dataset extracted from the port information system is described and analyzed. For the application of the GPS tracking data, a simulation model of the container terminal ship operation is constructed. As an application example, the efficiency and the flexible dispatching method of the trailers that served the GCs are compared and analyzed by running different simulation scenarios, and a resource dispatching policy is recommended.

2 LITERATURE REVIEW

A container terminal represents a complex system with highly dynamic interactions between the various handling, transportation, and storage units and incomplete logistics planning and incomplete knowledge about future events (Günther and Kim 2006). Given the randomness and complexity of the terminal, simulation technology is considered an effective research tool for researchers. Many recent studies used simulation technology to study the container terminal, especially the scheduling, routing, and dispatching problem of the container handling equipment and yard stock problem. For the quay side, Legato, Mazza, and Trunfio (2008) presented two OR models to study the GC scheduling problem and to minimize the ship overall completion time. Clausen and Kaffka (2012) developed a GC handling task-sequencing strategy. For the yard operation, Guo et al. (2008) used mathematical modeling and simulation to study the yard crane-dispatching problem. Sgouridis and Angelides (2002), and Van Asperen, Borgman, and Dekker (2010) evaluated the different container stacking rules by performing simulation models.

Vehicles are used to transfer the containers among the yard and the quay/yard/yard and the outside. Automated guided vehicles (AGV) or trailers/trucks are commonly used as terminal vehicles. Yang, Choi, and Ha (2004) presented a simulation model and a procedure governing the transport vehicles of automated container terminals. Lee et al. (2007) studied the influence of different designs of vehicle lanes on the yard crane efficiency. Because shortening the ship dwelling time at the berth is the most important goal of the terminal operation, the problem of dispatching vehicles that served GCs has been studied by several researchers. Bish et al. (2005) demonstrated that the greedy algorithm (give 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 the performance is reasonably effective. Cheng et al. (2005) proposed a network flow model to solve the AGV dispatching problem, specifically, to minimize the total AGV waiting time. Briskorn, Drexl, and Hartmann (2006) present an inventory-based consideration to assign the AGV to the GC that has a relatively small number of AGVs currently assigned. However, in this study, the flexible vehicle dispatching method using current resources under the different GC workload is analyzed by performing the simulation model.

Liu and Takakuwa (2011) proposed a simulation approach for collecting the required data from real-time tracking data to model an entire operations process at a container terminal. Additionally, GPS has been used to collect real-time tracking data for the simulation of an open pit copper mine 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 the productivity in construction.

3 BASIC DESCRIPTIONS OF THE CONTAINER TERMINAL

3.1 Nabeta Pier Container Terminal at the Port of Nagoya

The port of Nagoya is located at the center of the Japanese Archipelago, whose hinterland, Aichi Prefecture, is the home of Japan's automobile industry. The terminal in this study, Nabeta Pier Container Terminal, is the largest terminal 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 cargos handled at the Nabeta Pier Container Terminal. Because of the geographically short distance between the port and predominant trading partners, regular weekly vessels with a small quantity of containers account for the majority of loads.

A part of the facility layout at the Nabeta Pier Container Terminal is presented in Figure 1. The container handling equipment consists of GCs, TCs, trailers, and trucks in this study. GCs located at the quay side are used for loading/unloading containers to/from ships. TCs located at the yard are used to move containers to/from trailer/truck or to relocate containers inside the yard. The distance scale of the container terminal is marked on the map. The routing directions of the trailers/trucks can also been observed. The yard has 18 blocks and 24 TCs. One or 2 TC are dispatched to each block. There are 40 bays in a block, and each bay consists of 6 rows by 4 ties. The case of one berth with 3 GCs are considered in this study for simplicity, whereas there are actually two berths with 6 GCs. A SC yard is also present in the terminal, which is omitted in this study.

Typical transaction between the international trade cargos processes and the container terminal is as follows (export cargos flows are shown from steps 1 to 7 and import cargos flows, which are marked in the brackets, are shown from steps 7 to 1):

Step 1. Cargos are moved into (out of) the bonded warehouse.
Step 2. Cargos are stocked and sorted at the bonded warehouse.
Step 3. Cargos are packed (unpacked) into (from) the container.
Step 4 . Containers are delivered to the container terminal (bonded 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.
Step 7. Containers are loaded (unloaded) onto (from) the ship.

Steps 1 to 4 at Nabeta Pier are processed at the bonded warehouse nearby the container terminal. For simplified container handling process for one ship, the following procedure is examined. At least one day before the ship arrives, the export containers are gradually carried into the yard by truck. All of the export containers waiting for loading would be gathered a few hours before arrival of the ship. When the ship is arriving at the berth, import containers are unloaded onto trailers that transfer these containers from the quay 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, the import containers will be carried out sequentially after the ship's arrival by truck. Using the GPS and RFID technology, the movement information of the containers operated by TC in the yard is tracked and saved in the system.

3.2 Nagoya United Terminal System

The Nagoya United Terminal System (NUTS) is used as the information platform for all the container terminals in the Port of Nagoya, supporting the container ships, container handling equipment and yard stock control. Figure 2 shows the container flows on the terminals and information flows tracked by the NUTS. The Control System sends the 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 movements of the containers in/out of the gate, shifting during the yard, loading/unloading to/from the ship are recorded in the data file simultaneously.

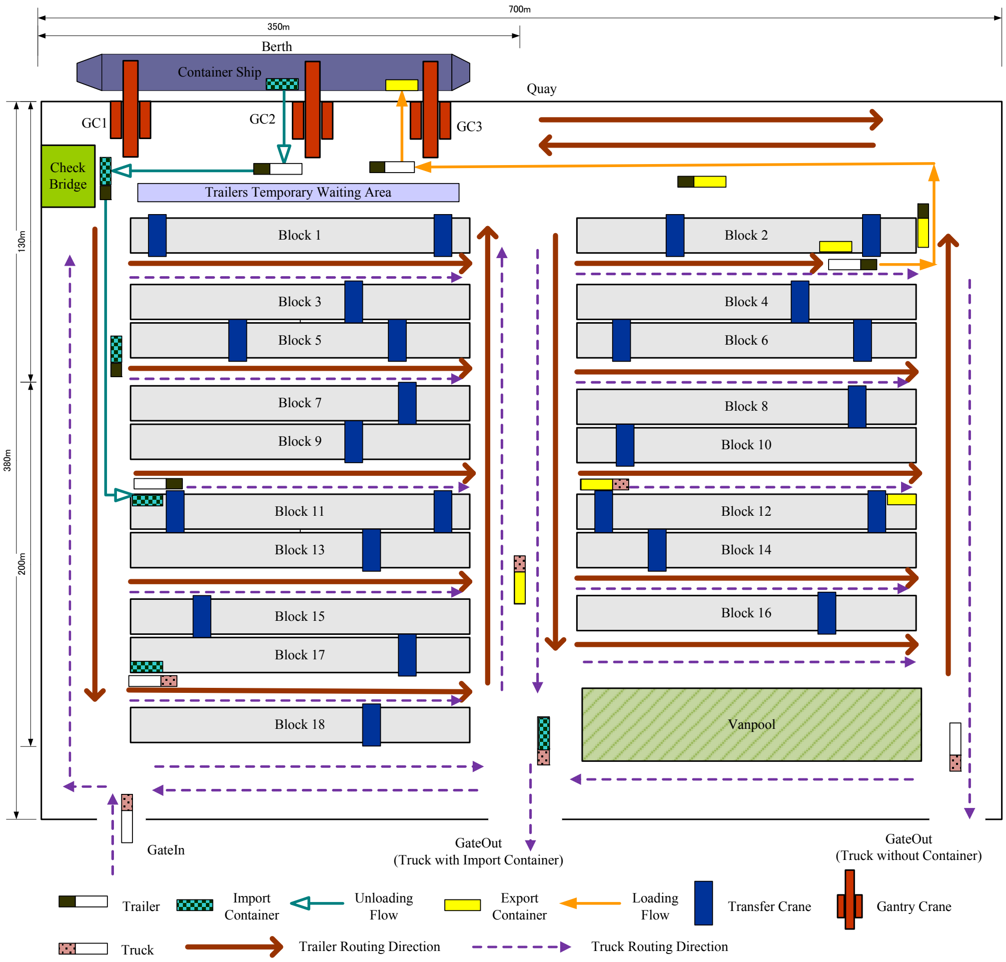

Figure 1: A part of the facility layout at the Nabeta Pier Container Terminal.

Each container's attributes (No., Size, Type, Height and Weight) were recorded. Through the unique container ID, the entire dataset describing the container handling processes and the information of the related ship can be obtained.

A series of dataset examples extracted from the NUTS are shown in Table 1. 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 Block`13`, Bay `40/41`, Row `6`, 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 GC`2`. At `1:28`, the operation was completed at the `21`st 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 (Bay`34`, Row`00`, Tier`84`, Dock) is recorded. The ship operation time (9 hours 35 minutes) and dwelling time (9 hours 56 minutes) can be calculated.

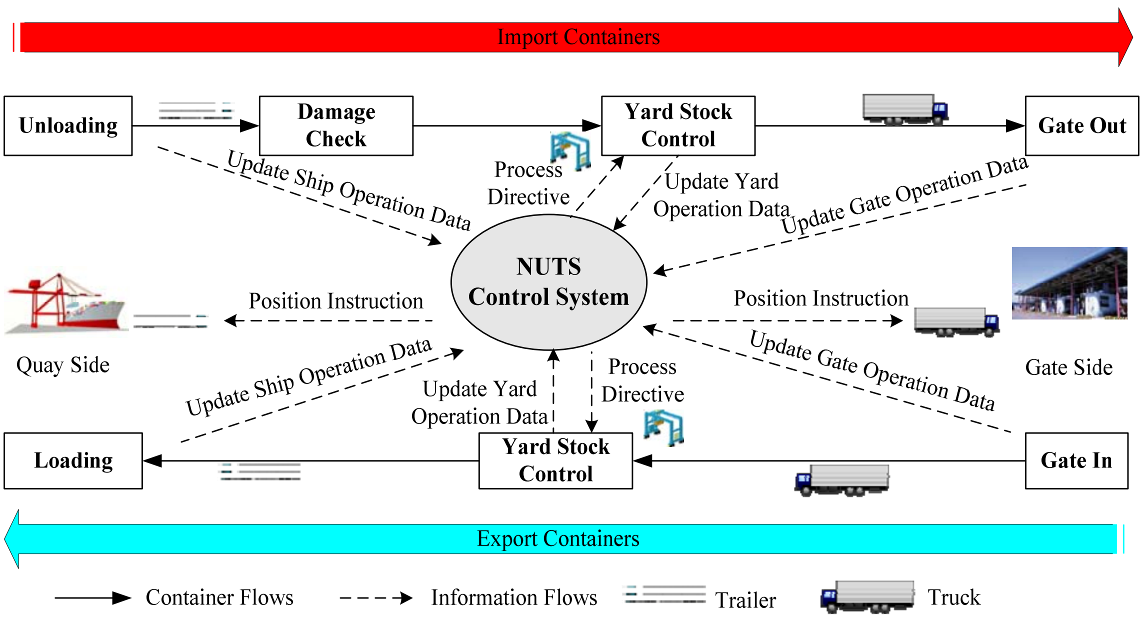

Figure 2: Container flows on the terminal and information flows in the NUTS.

Table 1: A series of dataset examples extracted from the NUTS.

(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—loaded 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

Considerable data were recorded in the system, and extracting useful data from large and redundant datasets is important. The operation data of each piece of container handling equipment can be sorted sequentially. The data tracked by GPS and the statistics collected from the terminal can be processed for use as input data for constructing the simulation to solve the problem and improve container handling equipment efficiency.

4 SIMULATION MODEL

4.1 Vehicles Dispatching Problem and Assumptions

A solution to the dispatching vehicles problem aims to dispatch a limited number of trailers that served GCs to transfer loading/unloading containers from/to the yard for ship operation at the quay side. A proposed solution to this problem is analyzed in this study. Four trailers usually serve 1 GC while the ship is in operation at the Nabeta Pier Container Terminal. A better dispatching policy with current resources is being considered by port managers. For the economics of experimentation, a simulation model with historical GPS data is constructed to analyze the dispatching problem.

Each container that needs to be transferred during the shipping operation is referred to as a job. The greedy dispatching method (Bish et al. 2005), where the current job is dispatched to the first available trailer, is adopted in the study. Although the greedy dispatching method is not the optimal method for the multiple GC model, this method is an appealing solution procedure due to the simplicity of the method, which is easy to perform for real-time control.

For the simulation construction, several assumptions are made in the study.

- Three GCs serve 1 ship at a berth. Twelve trailers serve the GCs.
- 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 the unloading jobs of all the GC have been completed.
- TCs are always available, and the number of TCs deployed in the stocks has no influence on the system.
- The temporary waiting area of the trailers is between the quay and yard, and this area can be observed in Figure 1. Trailers will return to the waiting area after completing the current job.
- The 20f and 40f containers are not distinguished, so the trailer can only carry a single container at one time.
- The proficiency of the operators who drive the GCs, TCs, and trailers has no influence on the system.
- Export and import containers are stocked at different blocks in the yard (LD blocks for export containers and UL blocks for import containers). Import containers are taken away 1 h after being loaded on the yard.

4.2 Simulation Model Construction

Based on the container handling processes of the real container terminal and the GPS data obtained from NUTS, 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 with the Simio modeling software, version 6.97. Figure 3 shows the main logic chart for the As-Is Model.

The first part of the logic chart is the container ship arriving logic, designed such that the ship arrives at the berth and creates the containers needed to be handled by each ship. 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 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.

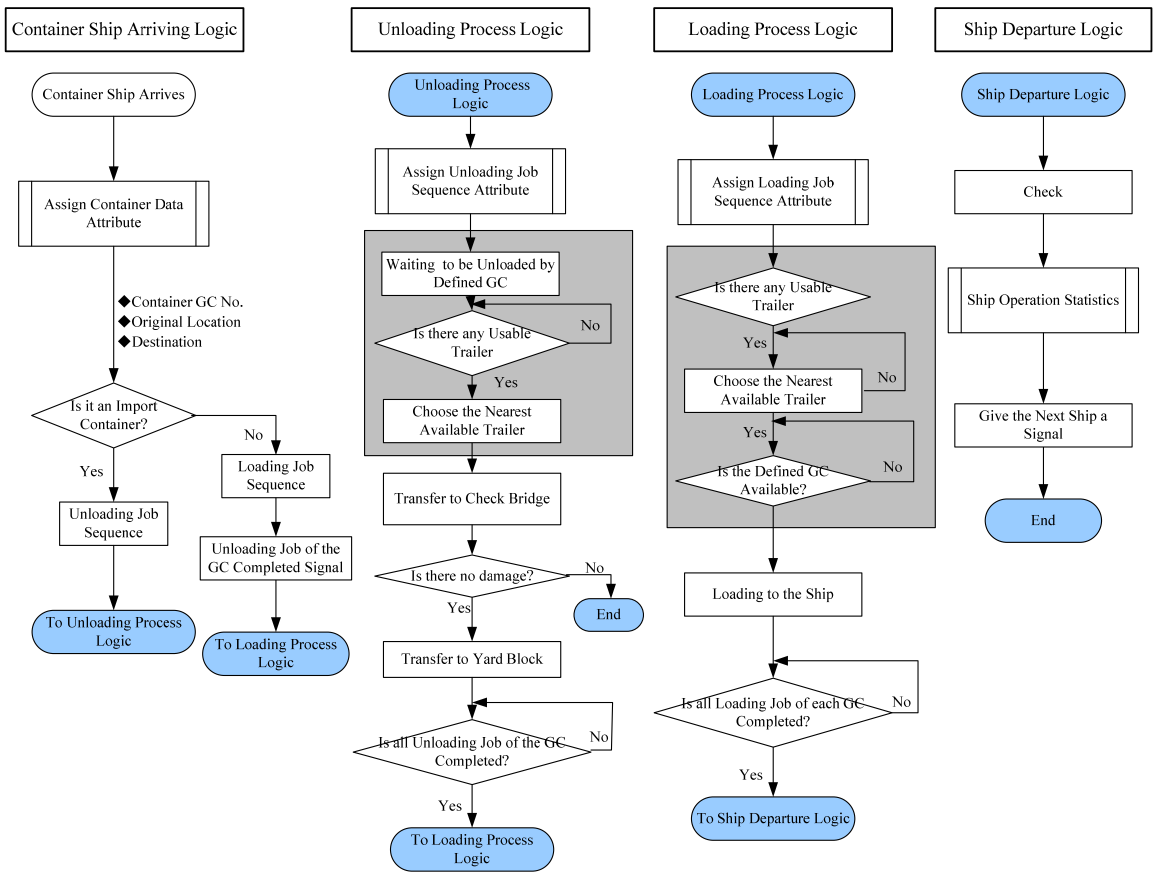

Figure 3: Logic chart of the simulation model.

4.3 Input Parameters

In addition to the GPS tracking data, statistics were collected from interviews with the staff during the investigation of the Nabeta Pier and are used as input parameters. The simulation will be performed for 3 months. Because the steady-state simulation is appropriate, the warm-up period is selected as 1 week (6 workdays), and 20 replications are performed. To ensure simulation randomness similar to the real system, the main parameters are collected and the random distribution data analysis is set in the As-Is Model. Table 2 shows the list of container terminal operation parameters. The distance between the block and quay is on the basis of the distance scale shown in Figure 1. In the As-Is model, 4 trailers are assigned to each GC. Furthermore, the workload of each GC is assumed to be same.

4.4 Simulation Results

After the simulation model has been generated, verification and validation of the model are necessary.

By running the simulation model, the container handling processes can be understood visually. Furthermore, the model can be executed continuously for a long time period and multiple times. 3D animation is supported as a part of the modeling process in the Simio modeling software (Kelton, Smith, and Sturrock 2013). The model can be confirmed dynamically and vividly. A part of the screen image for the simulation model is shown in Figure 4.

Table 2: Parameters on major container terminal operations.

Items	Description	Parameters
Berth	Capacity	1 (ship)
Gantry Crane	Number of units held	3 (units)
	Processing time	TRIA (108, 120, 138) (seconds)
Check Bridge	Number of units held	1 (unit)
	Processing time	TRIA (26, 30, 32) (seconds)
Transfer Crane	Processing time	TRIA (44, 58, 70) (seconds)
Trailer	Number of units held	12 (units)
	Travel speed	25 (km/h)
Block	Number of units held	8 (units)
	UL block No.	3, 4, 7, 11
	LD block No.	1, 2, 5, 8
Setting-up Time	Between unloading and loading	Uni (25, 32) (minutes)
	Between two ships arrival	5+Expo (33.2) (minutes)
Workdays	From Monday to Saturday	6 (days/week)
Shifts	Shift No.1	8:00-12:00
	Shift No.2	13:00-17:00
	Shift No.3	18:00-22:00
	Shift No.4	23:00-3:00

TRIA= triangular distribution; EXPO = exponential distribution; UNI= uniform distribution.

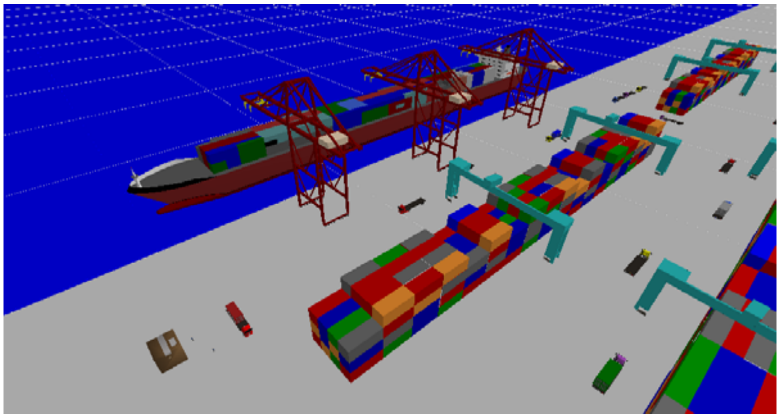

Figure 4: A part of the screen image for the simulation model.

The model validation is based on comparing the results from running the simulation model to the existing data statistics from the NUTS. The number of loading and unloading containers that are handled and the number of the ships that arrive on workdays during a week are used for comparison. After twenty replication is performed, a comparison of the simulation results and the real data is shown in Table 3. The actual values from real system fall within the range of resultant values by performing simulation for the all of the performance measures. Therefore the proposed procedure and the resultant simulation model can represent behavior of the real system.

Table 3: Comparison of the simulation results and the associated actual data.

Performance Indicators (units)	Resultant Values Obtained by Performing Simulation	Associated Actual Values
Number of Processed Unloading Containers	Min 3892, Avg 4971.55, Max 5926; 95%CL 4743.69 – 5199.42	5001
Number of Processed Loading Containers	Min 3486, Avg 4299.2, Max 5023; 95%CL 4105.66 – 4492.74	3709
Number of Ship Arrivals	Min 31, Avg 35.2, Max 40; 95%CL 34.18 – 36.22	40

Observation Intervals: Min, Avg, Max, 95%CL

Ship operation efficiency is investigated in this study. The total number of completed jobs in the period can be used as performance measure. After performing the As-Is model, the 95% confidence interval of an average number of the completed jobs in twelve weeks is [104112.6, ±648.44]. The result of As-Is model is used as a baseline to evaluate the proposed scenarios.

5 APPLICATION

5.1 Scenarios Construction

A large variety of analyses can be performed by using the simulation model. In this section, an application is described to examine the numbers of trailers allocated at the associated container terminal Although the trailers are a relatively low-cost resource in the container terminal, making full use of the existing resources is an important issue. In the recent system, four trailers usually only served one GC that are assigned to ship operation. Therefore, increasing the flexibility of trailers is expected to improve the efficiency of the ship operation. A series of scenarios, which are called the To-Be model, are shown in Table 4. 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 Set 1, 2, and 3 are four units. The trailers in Set 4 are referred to a free trailers, which can serve any of the GC when the job requires a trailer.

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

Table 4: 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 5: The GC workload ratio under the different experiment 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%

5.2 Comparison Among Scenarios

Simulation experiments of the corresponding To-Be models are executed with 20 replications, and 95% confidence interval for the average number of the completed jobs are obtained, as shown in Figure 5. The resultant results on the associated scenarios are represented by polylines.

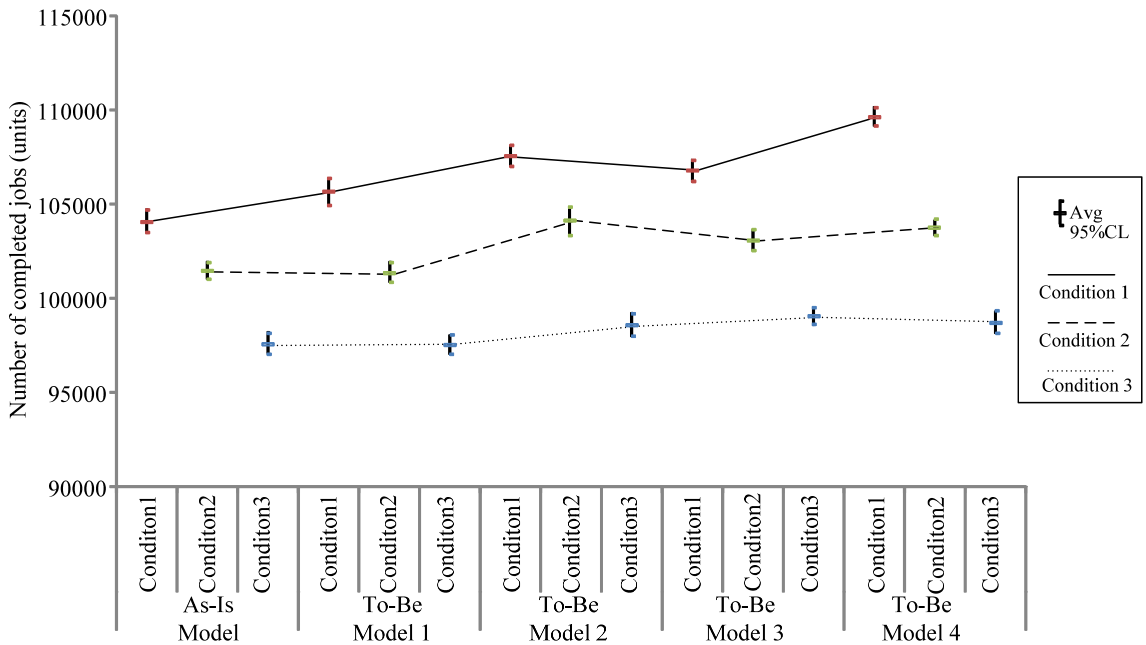

Figure 5: Results of the To-Be models under the three conditions.

From the result obtained by executing 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 2 performs best under the condition 2, whereas the scenario of To-Be Model 3 performs best under the condition 3. Thus, the flexible dispatching method can be performed effectively in the experiment.

6 CONCLUSIONS

The GPS tracking data recorded in the port information system are clarified in this study. For application of the data, a simulation model of the ship operation processes at a container terminal based on the historic GPS tracking data was constructed as an example of application. Different dispatching scenarios of the trailers that served GCs are compared by the completed jobs number under the different GC workload of these scenarios. The results show that under the different workload ratio of GC, the proposed scenarios are efficiency and effective. Consequently, it is found that increasing the flexibility of trailers in shipping operations is a potential method to improving the port operation efficiency by using existing resources. The proposed procedure to construct simulation models of container terminal using GPS tracking data was found to be both practical and powerful.

Future studies will consider the container handling equipment dispatching problem with the different busy level in a time period. The busy level is influenced by seasonal factors and the geographic location of the terminal on the long-term schedule of the ship. Input parameters based on GPS tracking data generated on different busy levels will be studied.

ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to Mr. H. Takahashi and Mr. S. Suzuki of Meiko Trans Company, Ltd., for their cooperation in completing this research. The author Wenhe Yang also wants to thank the China Scholarship Council for supporting her study in Japan.

REFERENCES

Bish, E. K., F. Y. Chen, Y. T. Leong, B. L. Nelson, J. W. C. Ng, and D. Simchi-Levi. 2005. "Dispatching Vehicles in a Mega Container Terminal." *OR Spectrum* 27(4): 491-506.

Briskorn, D., A. Drexl, and S. Hartmann. 2006. "Inventory-Based Dispatching of Automated Guided Vehicles on Container Terminals." *OR Spectrum* 28(4): 611-630.

Cheng, Y.-L., H.-C. Sen, K. Natarajan, C.-P. Teo, and K.-C. Tan. 2005. "Dispatching Automated Guided Vehicles in a Container Terminal." *Supply Chain Optimization*, edited by J. Geunes and P. M. Pardalos, 355-389. New York: Springer US.

Clausen, U., and J. Kaffka. 2012. "Modeling of Handling Task Sequencing to Improve Crane Control Strategies in Container Terminals." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A. M. Uhrmacher, 3104-3113. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Ducruet, C. 2013. "Ports in a World Maritime System: A Multilevel Analysis." In *Methods for Multilevel Analysis and Visualisation of Geographical Networks*, edited by C. Rozenblat and G. Melançon, 121-140. Dordrecht: Springer Netherlands.

Günther, H.-O., and K.-H. Kim. 2006. "Container Terminals and Terminal Operations." *OR Spectrum* 28(4): 437-445.

Guo, X., S. Y. Huang, W. J. Hsu, and M. Y. H. Low. 2008. "Yard Crane Dispatching Based on Real Time Data Driven Simulation for Container Terminals." In *Proceedings of the 2008 Winter Simulation Conference*, edited by S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler, 2648-2655. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Kelton, W. D., J. S. Smith, and D. T. Sturrock. 2013. *Simio and Simulation: Modeling, Analysis, Applications.* 3rd ed. Pittsburgh, Pennsylvania: CreateSpace Independent Publishing Platform.

Kemme, N. 2013. *Design and Operation of Automated Container Storage Systems*. Heidelberg: Physica-Verlag HD.

Lee, L. H., E. P. Chen, K. C. Tan, H. C. Huang, W. Lin, Y. Han, and T. H. Chan. 2007. "A Simulation Study on the Uses of Shuttle Carriers in the Container Yard." In *Proceedings of the 2007 Winter Simulation Conference*, edited by S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, 1994-2002. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Legato, P., R. M. Mazza, and R. Trunfio. 2008. "Simulation-Based Optimization for the Quay Crane Scheduling Problem." In *Proceedings of the 2008 Winter Simulation Conference*, edited by S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler, 2717-2725. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Liu, Y., and S. Takakuwa. 2011. "Modeling the Materials Handling in a Container Terminal Using Electronic Real-Time Tracking Data." In *Proceedings of the 2011 Winter Simulation Conference*, edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, 1596-1604. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Sgouridis, S. P., and D. C. Angelides. 2002. "Simulation-Based Analysis of Handling Inbound Containers in a Terminal," In *Proceedings of the 2002 Winter Simulation Conference*, edited by E. Yücesan, C.-H. Chen, J. L. Snowdon, and J. M. Charnes, 1716-1724. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Shahandashti, S. M., B. Akinci, J. Garrett, and L. Soibelman. 2010. "Identification of Information Requirements Using Simulation for Supporting Construction Productivity Assessment." In *Proceedings of the 2010 Winter Simulation Conference*, edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, 3076-3087. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Tan, Y., U. Chinbat, K. Miwa, and S. Takakuwa. 2012. "Operations Modeling and Analysis of Open Pit Copper Mining Using GPS Tracking Data." In *Proceedings of the 2012 Winter Simulation Conference*, edited by C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, 1309-1320. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Van Asperen, E., B. Borgman, and R. Dekker. 2010. "Evaluating Container Stacking Rules Using Simulation" In *Proceedings of the 2010 Winter Simulation Conference*, edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, 1924-1933. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Yang, C. H., Y. S. Choi, and T. Y. Ha. 2004. "Simulation-Based Performance Evaluation of Transport Vehicles at Automated Container Terminals." *OR Spectrum* 26(2): 149-170.

AUTHOR BIOGRAPHIES

WENHE YANG is a Ph.D. student in the Graduate School of Economics and Business Administration at Nagoya University in Japan. She received her B. Sc. degree in Logistics Engineering from Tianjin University in 2010 and her M. Sc. degree in Economics from Nagoya University in 2013. Her research interests include the optimization of logistics systems using data analysis and simulation with ARENA and Simio. Her email address is harrykidywh@gmail.com.

SOEMON TAKAKUWA is a Professor in the Graduate School of Economics and Business Administration at Nagoya University in Japan. He received his B. Sc. and M. Sc. degrees in Industrial Engineering from the Nagoya Institute of Technology in 1975 and the Tokyo Institute of Technology in 1977, respectively. He received a Ph.D. in Industrial Engineering from Pennsylvania State University. He holds a Doctorate of Economics from Nagoya University. He holds a P.E. in Industrial Engineering. He is a corresponding member of the International Academy of Engineering in Russia. His research interests include the optimization of manufacturing and logistics systems, management information systems and simulation analysis on these systems in the context of hospitals. He has prepared the Japanese editions of *Introduction to Simulation using SIMAN*, *Simulation with ARENA*, and *Simio ad Simulation: Modeling, Analysis, Applications*. His email address is takakuwa@soec.nagoya-u.ac.jp.