A Simulation-based Testbed for Evaluating an Appointment System in Port Terminals

Vu Duy Duong
Department of Industrial Engineering, Pusan National University
Busandaehak-ro 63 beon-gil, Geumjeong-gu, Busan 609-735 Korea
Tel: (+82) 51-510-1483, Email: duyduongvu79@gmail.com

Hyo Jae Kim
Department of Industrial Engineering, Pusan National University
Busandaehak-ro 63 beon-gil, Geumjeong-gu, Busan 609-735 Korea
Tel: (+82) 51-510-1483, Email: rlay88@naver.com

Lin Gui
Department of Industrial Engineering, Pusan National University
Busandaehak-ro 63 beon-gil, Geumjeong-gu, Busan 609-735 Korea
Tel: (+82) 51-510-1483, Email: skipyoulow@hotmail.com

Kap Hwan Kim†
Department of Industrial Engineering, Pusan National University
Busandaehak-ro 63 beon-gil, Geumjeong-gu, Busan 609-735 Korea
Tel: (+82) 51-510-2419, Email: kapkim@pusan.ac.kr

Abstract. Congestion of trucks in container terminals has been one of serious problems in many ports from the viewpoint of not only operation cost but also environment. Appointment systems have been applied to some terminals for reducing the congestion. These systems usually pre-specify the quotas for the number of truck arrivals in each time period and will accept or reject applications based on the rule of first-come-first-served. Trucking companies are allowed to send their transporters when the quotas are still available in the terminal. Specific requirements of individual trucking companies may not be considered in the previous type of appointment systems. This paper proposes a different type of appointment system and discusses a simulation based testbed for evaluating the proposed appointment system. A virtual simulation model is introduced with the data extracted from the system. A stochastic analysis is performed to evaluate the system performance such as the waiting time of road trucks, and the system time of internal trucks.

Keywords: container terminal, appointment system, simulation, congestion

1. INTRODUCTION

Container traffic is growing rapidly due to the globalization of economic activities. As a result, the congestion becomes one of the serious problems in most of major ports. When congestions occur, trucking companies suffer from high operation costs, long turnaround times, and as a result, low margins. In addition, the environment will be polluted by trucks, and thus there will be many complaints from truck companies or local communities to container terminals.

There were earlier researchers who addressed this problem. Some studies only focused on the appointment method. Chen et al. (2013) proposed a method to control truck arrival groups and assign different time windows to the groups. Phan and Kim (2015) used a negotiation process for the appointment system for road trucks in container terminals. Guan and Liu (2009) analyzed the gate congestion and calculated the truck waiting cost by a multi-server queue model.

Appointment system (AS) is not only the most important management tool for improving resource usage in the terminal, but it may also be used to share detail requirements between the terminal and trucking companies. A trucking company usually makes an appointment (through web application, software, or by contacting the terminal directly) with following information: truck company name, the expected truck arrival time, the number and type of containers, etc. AS will check the remaining capacity of the terminal and will accept or reject the appointment application proposed by a truck company, or suggest a new appointment, which best fits both of the terminal and the truck company.

After developing AS, it is not easy to predict what will happen when it is deployed to real situations. Therefore, it will be very risky to use the developed AS in a real system immediately. This study addresses various issues for using a simulation environment before implementing a developed appointment system to enable analyzing the effect of AS, reduce the possibility of failures to meet goals of AS, and optimize the system performance. There are some studies about terminal simulation studies: Guenther and Kim (2006) summarized many different simulation models and algorithms in the terminal, while Yun and Choi (1999) applied a simulation technique to perform an operation analysis of ports.

There have been many studies about the appointment system and the simulation system in port terminals. However, there has been no paper which addressed the integrated system of the appointment system and the simulation system. This paper will discuss about how both the systems can be integrated, how to design the communication between them, and how to run the integrated system (Figure 1).

The appointment system is in the left hand side of Figure 1 including Negotiation System and Modification Process. This two-component system is connected to the simulation system as described in the right hand side process which consists of Container Handling Process, Updating Process, and Evaluation. Firstly, Appointment System has appointment information after being negotiated and modified, then store them in "Shared Database" which be used by MySQL. The Container Handling Process must also be connected with Shared Database, which collects and analyzes data in the storage, then assigns the corresponding container retrieved to a vehicle. After finishing the container handling, the data will be updated according to Updating Process. Then, Simulation is responsible for testing the system operation by collecting data and verifying the system through Evaluation process.

The simulation system sends information to appointment system through socket protocol. In the beginning of each day, simulation system sends the daily demand information to appointment system. Specifically, once the "Updating process" finish, simulation system send maximal number of possible appointment slot, to-be-changed appointment time, real arrive time and real system time to the appointment system.

In this paper, the remainder is organized as follows. In Section 2, we give a brief overlook of the appointment system, the simulation system, the integrated system, the structure, and functions of the appointment system. Section 3 describes the construction and workflows of the simulation. Section 4 explains how to integrate the appointment system and the simulation system by using database and functions. Finally, conclusions and an outlook of the future research are given.

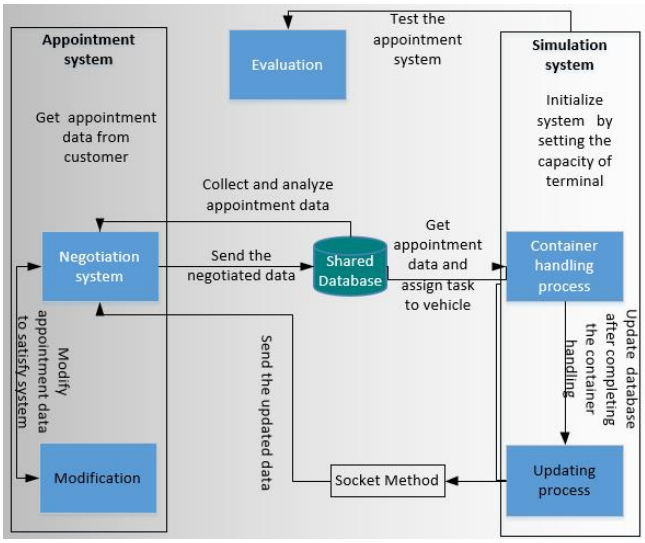

Figure 1: Communication between appointment and simulation systems

2. APPOINTMENT SYSTEM

In this system, there are three main functions (Figure 2): Workload Management System (WMS), Appointment Negotiation System (ANS), and Appointment Management System (AMS), which are described as follows:

a) **Workload Management System (WMS)**: manages information on workload in terminal:
- Defines storage resource unit (SRU set of blocks. Each SRU has an SRU_ID, which is stored in the data table.
- Provides positions of containers to ANS.
- Sets the maximum number of appointments: make a data table consisting of SRU, time window, maximum number of appointments.
- Manages priority service.

b) **Appointment Negotiation System (ANS):** manages the appointment process and manages the appointment results including reservation state, and expected waiting

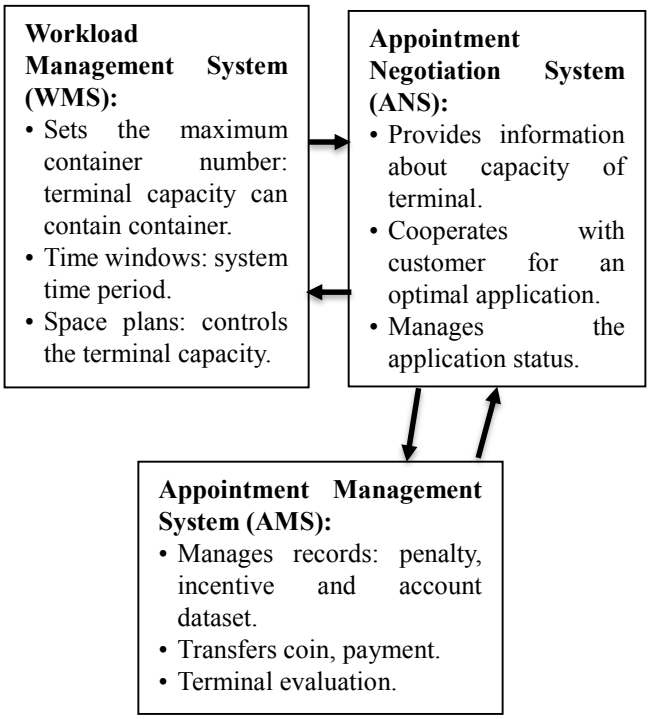

Figure 2: Structure of the appointment system

time. To negotiate appointment schedules, participants shall perform following roles: When a customer registers an appointment, ANS will show a detail time window table as in Figure 3, and the customer will select the item suitable for them. There are several levels of workload in a time window: low, normal, and high. If a trucking company select a time window with a certain level to handle a container, the trucking company must pay a certain amount of appointment charge. For instance, customer selects the fourth time window (equivalent to "Low" price time type), they will have to pay 80 coins per container and will receive 5 reward coins in their account. the coin reward can be used by the trucking company to reduce its payment when selecting next appointments.

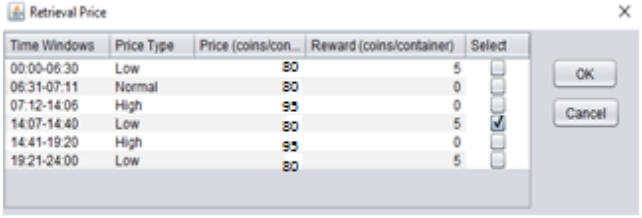

Figure 3: Appointment charge

ANS returns the acceptance (or rejection) decision to the applicant in real time. Trucking company applies an appointment and the appointment can be canceled by the trucking company. Additionally, an application can be moved to another time window if the limit on the maximum number of appointments is reached by encouraging the customers to move their appointments to time windows, which have lower workloads. For instance, when the customer applies for an appointment time, ANS will check the availability of that time slot. If the time slot is available, then there is no negotiation and the trucking company is assigned to that time slot; otherwise, ANS will suggest another time window with a lower level of congestion.

c) **Appointment Management System (AMS):** keeps records of appointment applications, changes the applications, actual arrivals of trucks, and the system time of each truck; evaluates the performance of the terminal and trucking companies.

3. SIMULATION SYSTEM

A simulation for testing an appointment system is modeled. Usually, it is impossible or too expensive to test and reconfigure a software system once it is deployed to a real situation. The software system can be investigated, and properties concerning the behavior of the actual system or its subsystem can be inferred. Simulation is a popular tool to evaluate the performance of a system, which already exists or was proposed, with different configurations of interest.

By using a simulation model, we will evaluate the proposed appointment system. The process will be as follows: containers are discharged from a vessel to terminal. Trucking companies send their applications for the appointments to pick up their containers. The appointment system checks the availability of slots and returns the rejection or the acceptance for each appointment. After a truck receives an appointment slot, it moves into the terminal. During the travel to the terminal, the appointment time may be changed considering the traffic condition. The expected arrival time of the truck will be calculated by the appointment system based on the truck's departure time, required travel time, and its updated position, which will be obtained using Global Positioning System and then sent to the terminal at a regular interval. When the truck arrives at the yard, a yard crane will perform re-handling operations and the retrieval operation for the truck. When the service for the truck by a crane is finished, it is informed to the appointment system. Details about the simulation process are described as follows:

a) Initial: the following information are stored in the database, such as the number of bays in a block, the number of slots in a bay, the number of empty or full slots, the capacity of the yard, the locations of containers, and the state of the appointment (waiting, processing, or finished).

b) Truck generation: a truck will be generated, with the following data: truck ID, task ID, arrival time, which will be stored into truck table. Then, applications of

appointments are sent to the appointment system. There are 2 cases:

- Application accepted: if the arrival time of the truck belongs to a time window with a positive number of available slots, then the appointment system accepts the appointment.
- Application rejected: when the terminal cannot accept any further appointment in the time window, WMS will select the most favorable arrival time of the truck and update its appointment time. If there is no available slot, then all information on this truck will be deleted.

c) There are 3 gates for the truck to enter the yard, as shown by Figure 4. The truck will wait at TR_waiting_in_gate and will not enter the yard until the yard crane is scheduled to serve this truck.

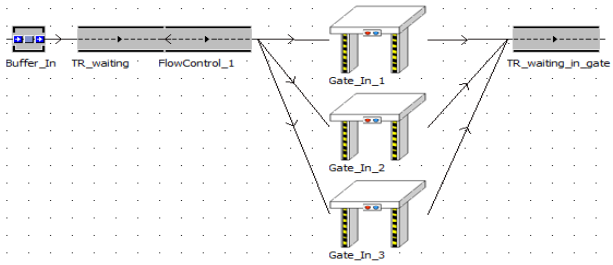

Figure 4: Gate in operation of truck

d) The yard consists of fifteen blocks, and an illustration of a block is provided in Figure 5 which shows 32 bays per block with 9 tiers and 6 rows slots per bay. As a result, we have total 480 bays with 25,920 slots in a yard. When a truck arrives at the yard, it will move to the corresponding block pre-specified in the list of tasks. Then, the truck performs the gate_out movement.

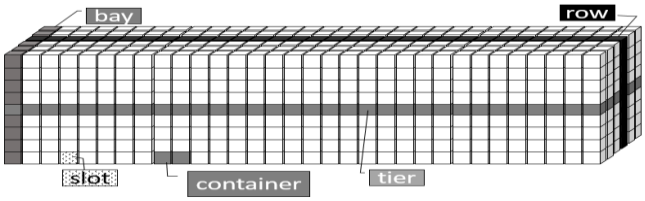

Figure 5: Structure of one block

e) After the carry-out operation of the truck is finished, the appointment system updates data related to the appointment in the database.

4. INTEGRATION OF APPOINTMENT AND SIMULATION SYSTEMS

After modeling the simulation and the appointment system separately, we integrate their databases through an interface which transmits data between them. We must ensure that all tables are consistent all the time. Because the data transmission can only be performed through the interface, changes in a side of the integrated system does not have any direct impact on the other system. The flowchart of the integrated system is given in Figure 6.

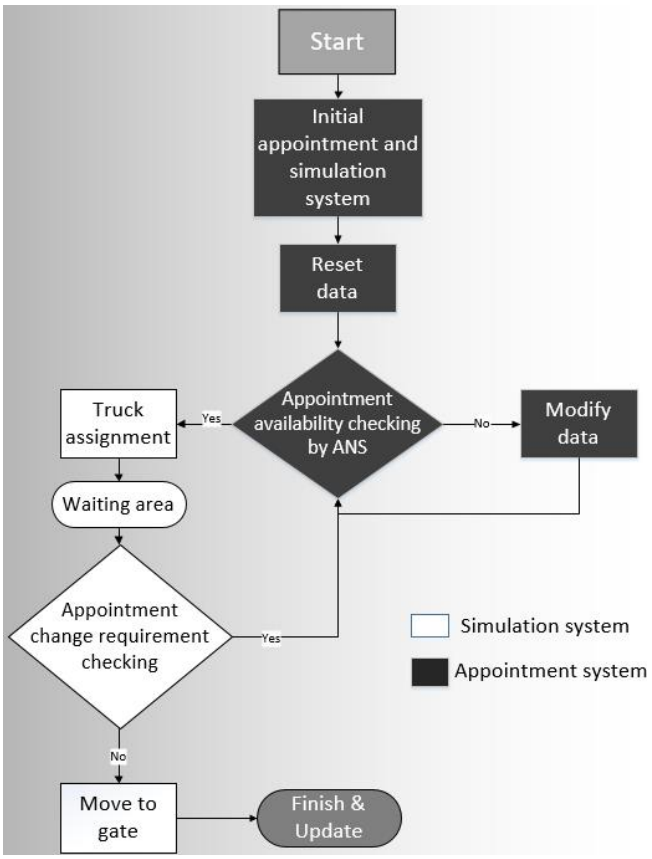

Figure 6: Flowchart of integrated system

We will describe function of methods in Figure 6 as follows:

a) Start: initializing appointment and simulation systems: when the appointment and simulation systems are initialized for the start of the simulation, we create lists of data including the distribution of trucks and appointments which will be implemented during the simulation (delivery time, truck name, container to be retrieved by the truck, expected truck arrival time at gate)

b) Reset data: the system will reset all data in the system to its default value, empty all slots in the yard, reset the simulation time, and reset all appointments.

c) Slot availability checking by ANS: when an appointment proposal is constructed, the appointment information will be sent to ANS. Then, ANS checks whether this appointment can be accepted considering the availability of appointment slots, which is restricted by the maximum

number of appointments for each time window set by the terminal operator. We have two cases:

- Modify data (Rejected case): ANS will modify this appointment considering various constraints from WMS (the arrival time of the truck, the container, the retrieval time, the number of containers, which can be retrieved based on the yard crane capacity in a certain time slot) and send it to the simulation system.
- Truck Assignment (Accepted case): ANS will update data in AMS database and send the information to the simulation system, then the simulation system provides the appointment data of a truck to the trucking company, including the arrival time, the travel time to gate, the location of the target container, then performs the truck movement toward the terminal.

d) Waiting area: the place where the truck waits until it enters the gate at the scheduled time.

e) Checking the necessity for appointment change: changing appointment times considering the expected arrival times, which are updated at a regular interval:

- When the expected arrival time is different from the appointment time by a large gap, the simulation system sends the revised appointment time to ANS and ANS will revise the appointment time accordingly, if it is acceptable. If the revision is not acceptable, then ANS attempts to find another suitable appointment time and informs it the simulation system.
- When the expected arrival time has only a small and acceptable difference from the appointment time, initiate the travel of the truck toward the yard.

f) Finish & Update: when the service for the truck is finished, the simulation deletes the appointment record from "Appointment database" and sends the result to ANS. ANS will update data of this appointment in WMS and ANS.

5. Simulation Results

WMS in appointment system will calculate number of appointments, slots which truck will obtain (Num_Op) in each time windows (2 hours) and each day, in order to obtain maximum number of possible appointment slots in each time window, are generated as shown in Figure 7.

When the simulation system begin, we have 14040 truck task schedules got from ANS shown in Table 1, with "Attribute" column contains the table of containers 'names to be retrieved, truck company name and expected arrival time. During the time trucks travel to the yard to retrieve container, they can change the appointment time because of some reasons such as congestion or private issues. In this case, the simulation system will use a coded function to check whether this time is satisfied and send the new time to appointment system through socket signals. Later, appointment system will modify the appointment time again.

Figure 7: Available appointment time windows

	time 1	string 2	string 3	table 4
string	Date	From (Hour)	To (Hour)	Num_of_Assignments
1	0.0000	0	2	8
2		10	12	1
3		12	14	2
4		16	18	4
5		18	20	2

When a truck appears in the task schedule as in Table 1, and a corresponding appointment slot exists, the truck will come to the yard for retrieving a container from its current location. The truck then leaves the terminal after the container is transferred from the yard crane to the truck. The truck processing result is demonstrated in the Figure 10 with the statistic of truck waiting time, truck service time and number of re-handling.

Table 1: Task schedule

	time 1	object 2	string 3	table 4
string	Delivery Time	MU	Name	Attribute
14014	99:19:43:29.0000	.TSBModels.MUs.Truck	TR14014	table514014
14015	99:20:11:03.0000	.TSBModels.MUs.Truck	TR14015	table514015
14016	99:20:45:52.0000	.TSBModels.MUs.Truck	TR14016	table514016
14017	99:22:12:15.0000	.TSBModels.MUs.Truck	TR14017	table514017
14018	99:22:44:41.0000	.TSBModels.MUs.Truck	TR14018	table514018
14019	100:07:22:10.0000	.TSBModels.MUs.Truck	TR14019	table514019
14020	100:07:22:30.0000	.TSBModels.MUs.Truck	TR14020	table514020
14021	100:07:51:23.0000	.TSBModels.MUs.Truck	TR14021	table514021
14022	100:08:07:47.0000	.TSBModels.MUs.Truck	TR14022	table514022
14023	100:08:11:17.0000	.TSBModels.MUs.Truck	TR14023	table514023
14024	100:08:20:41.0000	.TSBModels.MUs.Truck	TR14024	table514024
14025	100:08:21:44.0000	.TSBModels.MUs.Truck	TR14025	table514025
14026	100:08:44:29.0000	.TSBModels.MUs.Truck	TR14026	table514026
14027	100:09:47:35.0000	.TSBModels.MUs.Truck	TR14027	table514027
14028	100:09:49:48.0000	.TSBModels.MUs.Truck	TR14028	table514028
14029	100:09:54:25.0000	.TSBModels.MUs.Truck	TR14029	table514029
14030	100:09:59:12.0000	.TSBModels.MUs.Truck	TR14030	table514030
14031	100:10:03:20.0000	.TSBModels.MUs.Truck	TR14031	table514031
14032	100:10:54:41.0000	.TSBModels.MUs.Truck	TR14032	table514032
14033	100:10:56:05.0000	.TSBModels.MUs.Truck	TR14033	table514033
14034	100:11:13:18.0000	.TSBModels.MUs.Truck	TR14034	table514034
14035	100:11:37:59.0000	.TSBModels.MUs.Truck	TR14035	table514035
14036	100:20:22:58.0000	.TSBModels.MUs.Truck	TR14036	table514036
14037	100:21:02:35.0000	.TSBModels.MUs.Truck	TR14037	table514037
14038	101:04:00:14.0000	.TSBModels.MUs.Truck	TR14038	table514038
14039	101:06:43:41.0000	.TSBModels.MUs.Truck	TR14039	table514039
14040	101:06:45:51.0000	.TSBModels.MUs.Truck	TR14040	table514040

After running the simulation and appointment system for 55 days, the following statistic report is obtained:

- The "Production" tab in Figure 8 with the numbers 0% means that there is no problem caused by truck distribution in all the following statuses:
  - ✓ Waiting: truck's waiting until simulation can get truck's data from appointment system.
  - ✓ Stopped: truck has to be deleted because of missing data (name, travelling time, type…) or irrelevant with appointment system data.

- ✓ Failed: truck cannot be distributed because of simulation configure is error.

The "Transport" tab in Figure 8 shows truck do not stop or fail due to simulation system (Stopped and Failed value are 0%). The number of trucks has to wait during transportation from the time of "TruckGereration" to "Finish" (Figure 6) is low value (0.45%).

Class	Production						Transport					
	Working	Set-up	Waiting	Stopped	Failed	Paused	Working	Set-up	Waiting	Stopped	Failed	Paused
Truck	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.45%	0.00%	0.00%	0.00%

Figure 8: Truck Report

- Slots in the yard can be reused after retrieved, and only use another yard when have no empty slot in the current yard. In Figure 9 the empty time portions of yardbay1 and yardbay2 in block1 are very low (0-0.03%) but the empty time portions of yardbay9 and yardbay10 in block7 are high (100 %).

Empty Time

Object	Portion	Count	Sum	Mean Value	Standard Deviation
Yardbay1	0.00%	1	3:13.5000	3:13.5000	0.0000
YardBay2	0.03%	1	25:48.0900	25:48.0900	0.0000

Object	Portion	Count	Sum	Mean Value	Standard Deviation
YardBay9	100.00%	1	55:00:00:00.0000	55:00:00:00.0000	0.0000
YardBay10	100.00%	1	55:00:00:00.0000	55:00:00:00.0000	0.0000

Figure 9: Yard Report

Failed index of truck is 0% that means truck distribution is relevant to the data which customer registered in the appointment system, so that the connection between appointment and simulation system is not breakdown or interruption, and both of system can detect immediately when data changed through shared database.

Figure 10: Truck processing time statistical

	string 1	real 2	integer 3	real 4
string	ContainerID	TruckWaitingTime	RehandlingNumber	TruckServiceTime
2	C2	2012.85	5	942.88
3	C3	1290.48	5	938.94
4	C4	2917.55	5	948.88
5	C5	3274.35	5	885.31
6	C6	0.00	3	615.40
7	C7	3005.51	5	951.10
8	C8	3704.05	5	991.72
9	C10	0.00	3	644.63
10	C11	0.00	3	706.26
11	C12	0.00	3	698.04
12	C13	0.00	2	536.29
13	C14	234.30	3	708.26
14	C15	0.00	3	675.27
15	C16	0.00	4	833.94
16	C17	0.00	0	173.14
17	C18	0.00	0	177.36
18	C19	0.00	1	344.70
19	C20	0.00	4	766.88
20	C21	333.76	5	979.72
21	C22	0.00	3	644.13
22	C23	0.00	2	508.54
23	C24	0.00	2	493.43
24	C25	565.25	2	447.04
25	C26	0.00	2	534.05
26	C27	0.00	2	534.07

6. CONCLUSIONS:

This study introduces an appointment system for container terminals and a simulation system for testing the operation of the appointment system. An integrated system of the appointment and the simulation systems can be a good testbed for testing the performance of the appointment system and reducing the development cost and time, and updating the appointment system.

However, because the appointment system has a big scale, is a complex system, and used for many companies whose interests are different from each other, there are many issues to be answered before it is deployed into the real world.

The interfaces for the integration are only designed for the normal situation. However, there are many exceptional cases which the appointment system must respond to. Thus, further functions need to be developed in the simulation system, which covers those exceptional cases for the testing.

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REFERENCES

Guan, C.Q. and Liu, R.F. (2009) Modeling Marine Container Terminal Gate Congestion, Truck Waiting Cost, and Optimization. *Proceeding of Transportation Research Board 87th Annual Conference, Washington D.C.*, 58–67.

Chen, G., Govindan, K., and Yang, Z. (2013) Managing truck arrivals with time windows to alleviate gate congestion at container terminals. *International Journal of Production Economics,* **141(1)**, 179-188.

Phan, M.H. and Kim, K.H. (2015) Negotiating truck arrival times among trucking companies and a container terminal. *Transportation Research Part E: Logistics and Transportation Review*, **75**, 132-144.

Guenther, H.-O. and Kim, K.H. (2006) Container terminals and terminal operations, *OR Spectrum*, **28**, 437-445.

Yun, W.Y. and Choi, Y. S. (1999) A simulation model for container-terminal operation analysis using an object-oriented approach, *International Journal of Production Economics*, **59**, 221-230.