Journal of Navigation and Port Research International Edition
Vol.31, No.9 pp. 771~778, 2007 (ISSN-1598-5725)

A Simulation Study on the Efficiency of RFID at Container Terminal Gate System

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Abstract : *A container terminal gate is not only an entrance of containers, but also the first input point of containers' information. Therefore, to achieve the accuracy of container information, there are various containers' numbers recognition methods used. Gate productivity can significantly vary depending upon those recognition methods. Recently, RFID which is one of the u-IT businesses run by the Korean government is under consideration for application to the gate as an automatic system. If RFID is used, it is expected to have both the qualitative benefits through avoiding defects of other systems and the quantitative benefits by improving productivity. Hence, this study aims to provide some insight on the benefits of RFID, and to compare productivity of the existing gate system with the RFID gate system based on computer simulation.*

Key words : *Simulation, RFID, Gate, u-Port, Non-stop gate system, Container terminal, Productivity, Image recognition, Bar-code*

1. Introduction

Ubiquitous is a hot issue in IT all over the world. Korea has been developing ubiquitous-related technologies to achieve a powerful position in IT business. Coping with this trend, the maritime port industry is looking for the application of this technology into the maritime port system. Korea has several projects regarding this field, business projects for improving maritime logistics efficiency using RFID run by the Ministry of Maritime Affairs and Fisheries, u-Port business run by Busan Metropolitan city, and some other related business projects. Internationally, there is CSI led by the US and Smart Container business which is a security related RFID business. In order to apply ubiquitous technology in maritime business applications, a lot of research has been performed to find ways to apply various technologies. For instance, how to apply RFID or RTLS in container terminals. But the previous research mainly focused on middle-wear development regarding information process and recognition rate improvement. Because the research has focused only on developing business models and IT technologies which may lead to reductions in the number employees or accuracy and rapidity of simple information process, it could not find how it affects actual container terminal productivity using quantitative analysis. Generally, the container terminal gate is an input point of container information, which is the base of container terminal's information system and also it is an important point in terms of inspection of the container condition before entering the terminal. Moreover, it is a basis of management planning of yard allocation, yard equipment allocation and other activities. The Gate system may affect the community through disturbing the vicinity traffic flow caused by ineffective container gate operation and cause a traffic jam by stoppage of the electronic systems. Therefore, the aim of this study is to investigate the possibility of success of the RFID system in the container terminal gate, which has been expected to be the greatest possible area to adopt RFID in the container terminal, and explain its productivity in a quantitative way, in order to investigate the impact of RFID in the container terminal gate in terms of pre-transmission time of container information.

2. Current situation of terminal gate's recognition method

There are four types of gate operation systems commonly used in many world ports so far. First, manual system in the container terminal without automatic concept. Second, Bar-code system in the automatic concept terminal. Third, a letter recognition (camera image letter recognition, OCR) system in the container terminal with automatic concept. Finally, and the latest, a non-stop gate system

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based on the RFID system appeared in unmanned automatic terminals. This paper is focusing on the gate operation system in an automated container terminal.

2.1 Types of container gate recognition systems

1) Bar-code recognition system

Bar-code recognition system is the most common gate operation system in Korea. This method is very popular because of its convenience to operate, maintain and raise productivity, and inexpensive initial investment cost. However, Bar-code recognition system does not recognize the types of container carried by the vehicle because this method simply checks the vehicle number through recognizing Bar-code cards on trailers. In addition, if it can not receive any information from the transport company in advance, it is impossible to transact container data. It means that container data should be transferred to the terminal system before starting transportation; otherwise the system cannot work properly.

2) Letter recognition system

The function of the letter recognition gate system starts with a camera taking pictures of container and vehicle numbers and then extracting numbers by software. At present, this system is considered the strongest security system compared to other systems. Moreover, because this system is able to recognize the container and vehicle numbers simultaneously, it is expected to remove the errors of carry-in/out in advance, the errors which often happen in the Bar-code system. Since this advantage of the letter recognition system is attractive to container terminals which are developing automated systems or applying non-stop gate systems, they prefer to use this kind of gate system. However, this system has fatal disadvantages that make terminals avoid using this system i.e. decreasing of recognition rate over time (initial stage recognition rate is over 90% though) and high building and operating costs, three times higher than other systems (Kim and Kim, 2006).

3) RFID recognition system

This system is already used in our life in the ubiquitous sense. The standard frequency of the container tag and the frequency of logistics vehicle tag almost complete their international standardization. Therefore, the RFID operating method will create benefits in many aspects. The RFID recognition is being used in container terminals especially in Busan as a business case, though it is being used as an assistant system since it has not been connected to the terminal operation system. But many container terminals are considering this system regarding its accurate recognition rate which is almost 100%.

The common RFID recognition system is a system which adopts advanced ubiquitous technology. It avoids errors during carry-in/out, through recognizing container (433㎒ Tag) and vehicle (900㎒ Tag) numbers at the same time. This advantage may help to improve the security weaknesses as well as other RFID aspects. For instance, RFID has about 100% recognition rate, thus it may easily solve the problem of letter recognition's weakest point. RFID recognition system has been considered the only option to operate gates efficiently at the unmanned automated container terminals.

2.2 Current situation and characteristic: comparison of terminal gate recognition systems

The letter and Bar-code recognition systems can be distinguished in terms of their information recognition methods and whether recognizing container number or not. In this chapter, we investigate the characteristics, advantages, and disadvantages of Bar-code and letter recognition systems that both have been applied to the container terminals in Korea (Choi et al., 2005; You et al., 1998) as shown in Table 1, and present the differences between these two recognition systems and RFID system using quantitative analysis.

Table 1 Comparison of dis/advantage between Bar-code and letter recognition method

	Bar-Code	Letter
Characteristics	· Not checking container freight, only checking driver's ID card and collating with vehicle in the COPINO information from transport company	· After image data processing of container's and vehicle's number in the recognition program, data processing by collating with pre-delivered COPINO documents
Pros	· Comparatively easy and flexible to construct system for operation · Recognizing/processing only bar-code, keeping complete system as long as without outside intervention · Convenient system operation and maintenance	· Pre-cutoff exceptional items generated from differences between actual data and pre-information · Raising marketing effect with many advanced facilities against rival terminal
Cons	· Necessity additional countermeasures for errors generated by gaps between actual data and pre-information (Exist probability of freight which has different data from Bar-Code Data: necessity of checking by naked eye) · No guarantee of comparative predominance against rival terminal	· Limitation of recognition (dirty number plate and unique font), expensive investment cost for increasing recognition · Required additional M/H for manual data work · Hard system operation and maintenance · Bad compatibility

2.3 Comparison of success factors by gate recognition systems

As summarized in Table 2, this chapter deals with evaluating technical success factors based on the analysis of advantages, disadvantages, and problems of each gate recognition system. Development of RFID/USN (Radio Frequency Identification/User sensor Network) technology and the trial case of applying these various technologies to the gate system will help to check the actual container number, and then fostering the security and accuracy of information process. However, regardless of the gate recognition system, checking the work and recording at the last stage of shipping still need to be done manually and seen by eye. But if CPS (Container Positioning System) is adopted, the worker on the deck of the main ship will be in charge of those final checking and recording activities. Thus, the recognition method has only the question of whether it is worthy in terms of minimizing employee requirement. The cost aspect criteria is examined in Table 2, the technical success factor is given "Good", "Not Good", and "Bad". It is relatively a simple comparison without any efficiency and cost analysis (Kim and Kim, 2006). The result of analyzing technical success factors shows that the RFID recognition system and Bar-code recognition system have relatively high success factors than the other two systems.

Table 2 Comparison of technical success factors by gate recognition method

Technical success factor	Camera	RFID	Bar-Code
Freight security	NOT GOOD	GOOD	BAD
Employee & task amount	NOT GOOD	GOOD	GOOD
Recognition rate	NOT GOOD	GOOD	GOOD
Cost	BAD	GOOD	GOOD
Efficiency	NOT GOOD	GOOD	GOOD
System adaptation	NOT GOOD	GOOD	GOOD
P.R & AD effect	NOT GOOD	GOOD	NOT GOOD

Comparison of productivity at the container terminal gate can be evaluated in terms of gate transit time (Choi et al., 2005; You, 1998). Unfortunately, because the RFID gate system is under the government's show business, particular productivity indexes can not be shown at this moment. However, if a RFID tag is attached to the vehicle and container simultaneously, it will be able to build a strong system that combines the advantages of the high efficiency of Bar-code recognition systems and strengthen security of letter recognition systems. With higher productivity and reduction of employees' requirements accompanied with improvement of gate transit time, the qualitative comparison result showed that the RFID and Bar-code recognition systems are significantly higher.

We have compared an initial building cost and operating cost because advantage/disadvantage among gate recognition methods were not clearly appeared in operation side. The cost shown in Table 3 is real terminal data and the cost of RFID recognition method referred to data from RFID model business run by MOMAF. First of all, we assumed the initial building cost of camera image-letter recognition method to be 100%, then RFID recognition method recorded 29.74% and Bar-code recognition method recorded 18.50% (Kim and Kim, 2006).

Table 3 Initial building cost among gate recognition methods (Unit : Thousand Won)

Name of System	EA	Camera	RFID	Bar-Code
Image recognition SYSTEM	4	419,664	-	-
Image Supervisory	2	96,000	-	-
RFID Control Sys.	4	-	58,000	-
Image recognition Supervisory Sys.	1	-	25,000	-
Service Ticket Machine	4	50,400	50,400	64,800
Gate control zone	1	27,570	27,570	27,570
Exceptional vehicle handler	1	15,750	15,750	15,750
Issue a vehicle admission	1	6,450	6,450	6,450
Total cost		615,834	183,170	114,570
Rate of Building cost against Camera		100.00 %	29.74 %	18.50 %

* Taken from Internal data of H container terminal in Busan port which performed RFID model business of MOMAF

3. Simulation

3.1 Simulation for applying RFID to Gate

1) Simulation purpose

The purpose of this study is to measure and analyze the quantitative effect that may occur when the existing container terminal adopts the RFID system to their gate system. In other words, we are trying to observe the impact of RFID on the container terminal gate in terms of pre-transmitted time of container information. There is no research analyzing quantitative effects, thus this research considers measuring quantitative effects and using data collected from the RFID show business. Moreover, to guarantee objectivity, the simulation has been conducted by a simulator (CTMA-AS, berth yard gate capability analysis; CTMI-AI, equipments capability analysis; SIM

Result, depth and comparative analysis of simulation result) which is being used in a practical container terminal operation (Spain TCV, Japan OHI terminal, New port 1 phase terminal and Kwangyang 3-2 phase terminal).

2) Simulation flow and the basic structure

The overall flow chart of the simulation has been shown in Fig. 1. It consists of three parts, the simulation logic module, the basic input data module, and the result module of each scenario. First of all, DB and the parameter which is the sub-module of the setting module generate the data related to terminal gate, yard, and berth and so on. The functions of the container terminal are distributed to gate, yard and berth, thus we applied the simulation module for each function. In the next step, each function is linked to the others to form a whole container terminal system. The integrated simulation is conducted for a whole container terminal system and the result is analyzed. The simulation result is deduced for each part and scenario.

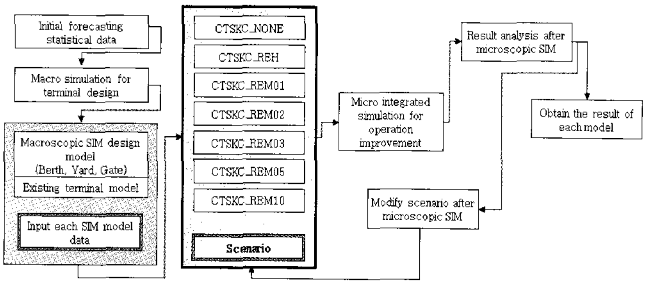

Fig. 1 Flow chart of simulation

The integrated simulation model for container terminals in this study was developed by discrete event simulation; the events that happened in the container terminal were collected first, and then closely composed Fig. 2.

Fig. 2 Even sampling for simulation

Fig. 3 gives a brief figure of module composition of each part and definition of statistics.

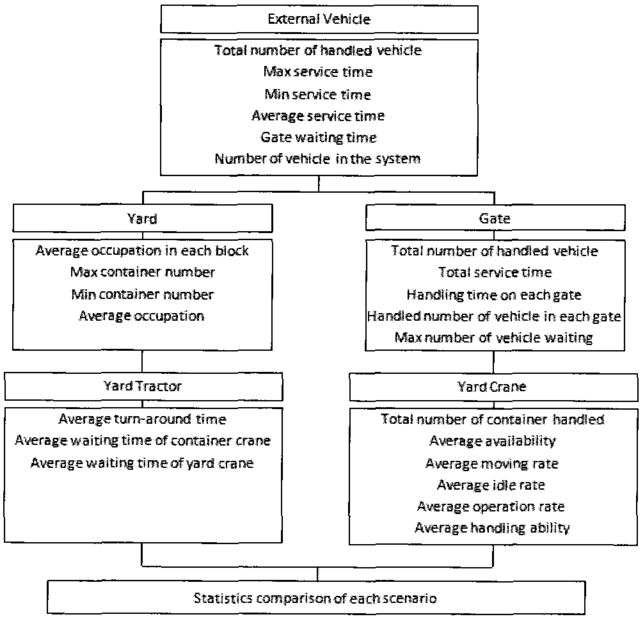

Fig. 3 Simulation statistical module

In general, it needs input data such as throughput distribution, gate related data, yard and berth data, handling equipment data and other relevant data to conduct the container terminal simulation.

3.2 Scenario assumptions and settings

1) Scenario assumptions

The basal scenario assumption is that the RFID system is already built in major positions on the route of container transportation and the gate and yard systems. The detail assumptions of each position and the container terminal system are as the following:

Assumption 1 : Build 900㎒ and 433㎒ RFID system at inland ICD and every CY to collect the container's outbound pickup data.

Assumption 2 : Build 900㎒ and 433㎒ RFID system in consignor's warehouse and gate of logistics center to collect departure data.

Assumption 3 : Build 900 ㎒ and 433㎒ RFID system and data collecting system to get the container and vehicle transit time data at the transportation route and toll gate for tracing container after it leaves consignor's ware-house or a logistics center.

Assumption 4 : Build 900㎒ and 433㎒ RFID and data collecting system to get the container and vehicle transit time data at the highway or a resting place on major transportation routes.

Assumption 5 : Collect transit information at major positions of assumption 3 and 4 and build total tracing system for providing real-time vehicle and container location tracking service through comparing COPINO data, these data will be provided to people who are involved in this business.

Assumption 6 : Build 900㎒ and 433㎒ RFID system and data collecting system for checking the vehicle and container arrival and transit information at the gate of container terminal and inland ICD.

The suggestion of the system's construction plan shown in the assumptions has been proposed as an available system applied on improving efficiency of maritime logistics businesses which is one of projects of Korea government's u-IT business.

2) Scenario settings

Basically, this study aims to compare the existing terminal operating system with the RFID system and find the differences between these two systems regarding turnaround time in terms of yard utilization, time reduction in gate carry-in/out, waiting time of vehicle inside of yard, and number of T/C rehandling. Thus, seven scenarios are generated based on transit time of pre-information.

The scenario that receives pre-information by the RFID system consists of 5 different receiving time levels: 1 hour before, 2 hours before, 3 hours before, 5 hours before and 7 hours before. Thus, the expected result of this simulation is to figure out the actual factors that affect improving productivity quantitatively by considering differences of time notice and comparing the RFID system with the existing system and the first scenario which is the optimal situation. First scenario is about the ideal terminal that generates a standard productivity without any re-handling or vehicle queuing situation or any limitation i.e. optimal situation of simulation. Second scenario is considering general operating system of container terminal to find the comparison factors by measuring its productivity. It represents the existing terminal operating system that means containers enter the gate without any pre-information. This scenario is a contrast for comparing with the RFID system. Third scenario describes the situation that the container pre-information is received from the vicinity of the Busan toll gate, 1 hour before arriving at the gate. Forth scenario is the situation that the container information is delivered from the RFID reader on the middle of the highway 2 hours in advance. Fifth and sixth scenarios are the cases of departure from the toll gate of capital area. The seventh scenario is the case of departure from the final destination of export and import consignor.

Table 6 Scenario structure

Scenario	Description
S#1	Optimal simulation which has no rehandling or waiting vehicle inside of terminal
S#2	Entering without pre-information (present system)
S#3	Entering a gate after receiving information 1 hr before arriving.
S#4	Entering a gate after receiving information 2 hrs before arriving.
S#5	Entering a gate after receiving information 3 hrs before arriving.
S#6	Entering a gate after receiving information 5 hrs before arriving.
S#7	Entering a gate after receiving information 7 hrs before arriving.

Although we suggested 7 scenarios, input data for all scenarios are the same. It is because the container pre-information affects the efficiency of the gate, yard and shipping planning (RFID adaptation does not directly affect the container terminal system structure).

Table 7 Simulation input data by scenario

Scenario	Annual (TEU)	Mean Lift/Ship	Berth	Block	Q/C	Y/Q	Y/T	GATE (In/Out)
S #1 ~ S #7	500,013	745	2	15	4	12	16	4 / 3

4. Simulation result analysis

To conduct the simulation study for the impact of the RFID' on the gate, yard and berth systems, first a flow chart is needed for each system since these three systems have different job procedures therefore they have different application procedures as well.

Basically, container terminal gate systems can be divided into two parts; carry-in and carry-out. Fig. 4 shows the result of the first scenario with a gate carry-in performance. X axis of each graph indicates 'time trend' and Y axis indicates number of gates that are generated in simulation. Since congestion and transit time at the gate can be observed by conducting the simulation in terms of given throughput and arrival pattern of trucks at the gate, we illustrated the number of gates that are taken by trucks with graphs to recognize congestion and congested time easily.

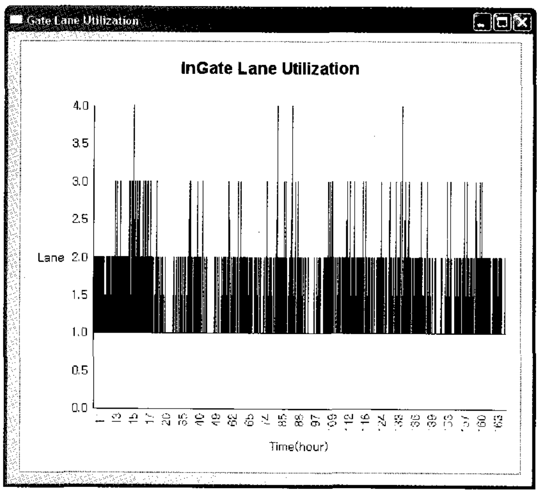

Fig. 4 Scenario 1 (In Gate)

The result of carry-out performance in Scenario 1 is shown in Fig. 5. Same as carry-in case, X axis indicates time trend and Y axis indicates number of gates that are generated in the simulation. The congestion and gate transit time in carry-out can be calculated by given throughput with simulation of yard system. The result of this analysis has been illustrated with a graph showing the number of carry-out gates in terms of sequence of trucks passing.

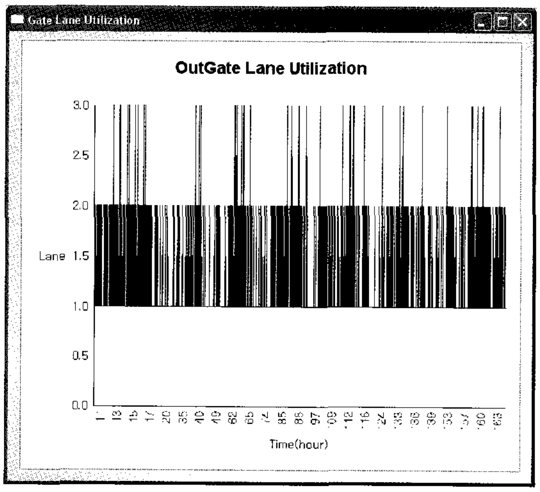

Fig. 5 Scenario 1(Out Gate)

Basically, comparing current Bar-code system with RFID system at the gate carry-in/out, RFID system has relatively shorter recognition time for reading the vehicles' and containers' numbers. Therefore, as shown in Fig. 5, the scenarios with RFID system have reduced the recognition time by an average 7 second in carry-in and average 4 second in carry-out compared to the second scenario.

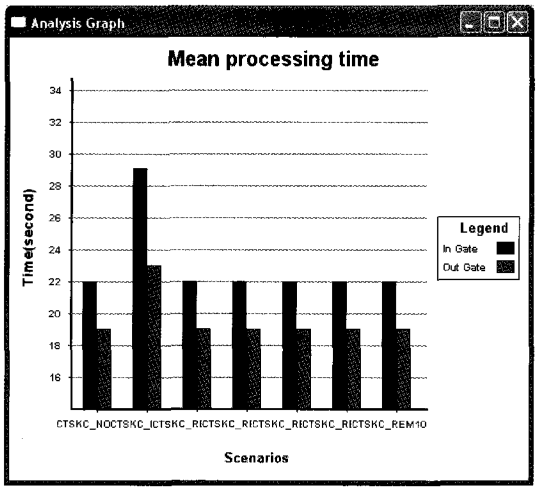

Fig. 6 Comparison average In/Out gate transit time by scenario

This result can be understood as just a reduction of recognition time, but this reduction of time can be a solution for the peak time congestion. Moreover, this result may affect other systems linked with terminal gate since the terminal gate is the starting point of spreading information and also is an important connection point it particularly reduces the number of trucks hanging around the terminal, turnaround time, and rehandling.

Table 8 Simulation result in Gate carry-in/out

Scenario	Total Passing Trailer #	In Gate #	Mean Service Time (Sec)	Out Gate #	Mean Service Time (Sec)
S# 1	3,089	4	22.24	3	19.96
S# 2	3,135	4	29.20	3	23.23
S# 3	3,153	4	22.69	3	19.79
S# 4	3,118	4	22.75	3	19.87
S# 5	3,105	4	22.58	3	19.98
S# 6	3,123	4	22.37	3	19.91
S# 7	3,117	4	22.61	3	19.82

As seen in Table 6, the gate transit time is considerably improved because the recognition time of the vehicle and container which adopted RFID system (no matter whatever scenarios) is reduced.

LDU(Location Display Unit) which is one of RFID recognition methods is able to support building with a non-stop gate system. This is expected to reduce the normal gate transit time by maximum 7 seconds. If this system is available to be used in practice, the gate productivity will be incredibly improved Table 7. However, it still needs to discuss how and where the place for container exterior damage inspection and seal examination is operated and located since this place was usually located in the terminal gate (Kim and Kim, 2006).

Table 9 Comparison productivity of each terminal recognition system

Classification	Gate transit time	Notice
Camera	avg. 45 ~ 50s	-
Bar-code	avg. 25 ~ 30s	-
RFID	avg. 19 ~ 23s	Vehicle 900MHz, Container 433MHz
	avg. 10 ~ 15s	Using LDU or SMS

* LDU-Location Display Unit, SMS-Short Message Service

5. Conclusion

More than 95% of container terminals in Korea are using Bar-codes as an automated gate system. Although this method has no object-detection system, with lower building costs and convenient operation, it has been stably operated through making up for the weak points. However, the benefits of an advanced system such as unmanned gate operation, a non-stop gate system and container object detection lead container terminal to consider various gate systems. So far, these attempts to come up with a new gate system have not been realized since it caused the problem of recognition rate and the excess of gate transit time. In this study, operation process and operational advantages and disadvantages of each gate building method have been investigated. Moreover, the productivity of the RFID system which is known recently as the most efficient system has been compared with existing gate systems. As shown in the simulation result, the RFID system is faster than the Bar-code system therefore productivity is improved in carry-in by 6.5 seconds and carry-out by 3.4 seconds. This means that about 22% of carry-in and 17% of carry-out productivity is improved. On the quantitative view, these results are shown to expect improvement of not only gate productivity but also container terminal yard productivity. Therefore, the simulation study on improvement of yard productivity should be performed in a future study.

There is no terminal which adopts the RFID gate system at this moment; however, if the government shouldered the cost of such a cargo automation system, then maybe some terminals might show interest in building an RFID gate system. Therefore, it is expected to measure the actual productivity improvement in the RFID gate system, thus, encouraging other terminals to adopt RFID systems

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Received 9 October 2007
Accepted 31 December 2007