Non-stop Automated Gate System based on a Digital Media with Wireless Communication Function

Hyung Rim Choi, Byung Joo Park, Joong Jo Shin, Yavuz Keceli and Nam Kyu Park

***Abstract*—** In order to go ahead in fierce competition to be a hub port, many major container companies all over the world are making every effort to improve their productivity through high-tech devices and information technology application. In particular, in case of container terminal gate, state-of-the-art technologies such as RFID (Radio Frequency Identification) and OCR (Optical Character Reader) are being adopted to recognize a container number and truck's plate number, to transmit the information on container location in a yard, and to prevent illegal opening of containers. But in most cases the container terminals are still using a bar code system for gate passage of trucks and containers, and also using paper documents (slip) for the delivery of the information on storage location of container in a yard. For this reason, most trucks have to stop at the gate of the container terminals in order to perform several basic jobs. To enhance the productivity of gate management, this study tried to develop a non-stop automated gate system based on wireless communication and digital media, so that trucks may not have to stop at the gate for the recognition of trucks and containers and also for the transmission of the information on container storage location.

***Keywords*—** Container terminal, RFID, Non-stop automated gate, Wireless communication, Digital media.

I. Introduction

ALONG with rapid globalization of the world economy and market opening, the importance of logistics industry is also steadily growing internally and externally, and also logistics volume is considerably increasing. To cope with increasing logistics volume, the environments of port logistics industry are also undergoing sweeping changes. Recently super container ships have emerged, and they usually call at hub ports, not visiting the other ports. In case of other small ports, small ships are carrying container cargoes. Accordingly, the hub and spoke system has been introduced to current logistics industry. Under this circumstance, major container terminals, the bridgehead of port logistics, are making efforts to become a hub port, while lowering the hire of their harbors, improving their service level. At the same time, they are investing huge money in the introduction of spearhead technologies for harbor construction, loading/unloading equipments, and operating system. All these efforts focus on enhancing the efficiency and productivity of their ports. For the enhancement of efficiency and productivity of container terminals, many high technologies have mainly concentrated on the operating information system and loading/unloading equipments (quay crane, yard crane, etc). In contrast, the studies on container terminal gate have not been made enough until now. Therefore, at present, lack of container and truck recognition and information transmission technology for gate management causes not only traffic jam but also manpower waste, consequently lowering the productivity of a container yard [1].

Many container terminal gates are now adopting a bar code-based gate system or an OCR-based gate system. In case of a bar code-based gate system, when a container truck arrives at the gate, its driver has to get his truck and container recognized by means of a bar code system, and receives the information on job order. But this bar code system takes a long handling time, and also the bar codes are sometimes lost and damaged. In case of an OCR-based gate system, a video classifier is used for the recognition of trucks and containers. But this also often causes errors, consequently leading to manual work [6]. For the solution of these problems, some researches have made for the application of RFID technology to the container terminal gate [2]. An RFID-based gate system made it possible to automatically recognize the trucks and containers, but it is impossible for this system to automatically transmit the information on job orders to the driver. Therefore, the gate management has not yet entirely automated, and so a truck has to stop at the gate in order to receive the job order written on a paper document (slip). For this reason, this study decided to make use of digital media devices, which enable wireless communication with RFID technology, for the development of a non-stop automated gate system.

II. Outline of Container Terminal Gate System

The gate of a container terminal is a physical interface between a container transporter and a container terminal where

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the responsibility for container management is shifted between the two. It also provides a truck driver with the information on the access to the container yard and storage location. Therefore, it can help that terminal operation is efficient, through improving job-handling capacity of a container terminal [3][4][8]. The jobs at the gate can be divided into three as shown in Table 1: recognition and confirmation, information management, and customer services [1].

Table 1. The general jobs of a container terminal gate system

Section	Contents
Recognition and confirmation	• Recognition of a driver, truck's plate number, container number and chassis number • Confirmation of container seal, weight, size, damage, and temperature
Information management	• COPINO management, delivery of job order information • Storage of container information, real-time information transmission to TOS (terminal operating system)
Customer services	• Provide customers including shippers and transporters with information on containers and related statistical data

Main jobs of recognition and confirmation, information management, and customer services at the gate were done manually by gate workers, and so the bottleneck often takes place at the gate. In order to solve this problem, an automated gate system has begun to be developed for the first time in late 1980s. For example, Los Angeles Port of United States introduced an automated gate system by adopting a video camera and a voice transmitter in order to reduce job handling time at the gate [7].

Recently, several cases of RFID technology application to the container terminal can be found. In Korea, under the leadership of the Ministry of Maritime Affairs and Fisheries, both RFID-based port logistics project (in 2004) and intellectual port logistics technology development project (in 2005) were conducted and laid a foundation of an automated gate system. Since 911 terror, the United States is implementing the policy of attaching an RFID tag to all the imported containers for the purpose of strengthening national security [5]. Like this, many cases of an RFID technology application can be found at the port logistics both internally and externally. But the problems they are now facing are shown in Table 2.

In spite of many efforts to improve the productivity of a gate by using an RFID-based automated gate system, there are still some problems, that is, the problems of recognizing a 433 MHz container tag and combined containers. Also, by using a paper document for job orders given to the driver, a truck has to be stopped, thus delaying the time for gate passage.

Table 2. The problems of RFID-based gate systems

Problems	Causes
Confirmation of gate passage	• In case of RFID tag attachment, recognition is possible within the distance of 100 meter. • But it cannot show whether the container has passed the gate or not
Delay of gate passage time	• According to the on-dock contract between a container terminal and a shipping company, examination has to be made as to whether the containers are in a good condition or not • Truck has to be stopped to confirm the information on job orders.
Recognition of combined containers (two 20ft containers)	• Interference by frequencies of each other • Frequency absorption caused by the quality of container material

In order to improve the productivity of a container terminal gate, the work process for the delivery of job order information, which is absolutely necessary for truck movement in the yard, has to be renovated. To this end and also to remove the work process of delivering the job orders by paper documents, this study developed a non-stop automated gate system.

III. Selection and Design of a Digital Media for Non-stop Automated Gate System

Unlike an existing automated gate system, in case of a non-stop automated gate system, container trucks need not to be stopped at the gate. Instead of using a paper document, digital media is used for the transmission of job order information. A dictionary defines a digital media, "It is a digital code-based electronic media or a format representing information." In this study we define it, "It is an electronic media for the transmission and confirmation of jobs order-related information including the location information of containers. For the development of non-stop automated gate system, first of all, digital media devices have to be selected. After that, the job order information written on the paper documents has to be analyzed. And the data to be contained in the digital media-based information transmission system should be defined.

A. Selection of Digital Media

The non-stop automated gate system where a container truck does not stop at the gate sends job order information of truck to the digital media by wireless communication. To select the optimum digital media for a non-stop system, this study has taken the following steps.

(1)Researches on various alternatives of digital media
- Researches on diverse digital media that are under R&D or prepare for commercialization have been made
- Selection of criteria for decision making through the analysis of diverse digital media characteristics

(2)Filtering
- Removing the digital media that are causing difficulties in the realization of a system in terms of cost or communication method

(3)Questionnaire and interviews with experts
- Planning of questionnaire survey
- Priority decision for decision making criteria through expert interviews. The respondents are container truck drivers, terminal gate managers, and decision makers responsible for an information system.

(4)Analysis of Results
- Selection of the optimum digital media with the results of questionnaire survey and interviews

According to the results, the possible alternatives are a mobile phone, PDA, web pad, DSRC (dedicated short-range communication), smart card and HUD. Also, the evaluation criteria for all the alternatives are: function (security and expansibility), cost, convenience (easy to handle and portable), and motion environment (considering the particular environments of a container terminal), as shown in Table 3. The priority of these criteria also has to be given for the selection of digital devices. The priority was decided by questionnaire survey whose respondents include container truck drivers, terminal operators, and decision makers in charge of an information system. As a result of this questionnaire survey, the priority was given in the order of cost, convenience, function and motion environment.

Table 3. Decision making criteria for selection of digital media

Cost	Digital media purchase price, maintenance and repair cost, and service charges
Convenience	When using digital media, is the data input and confirmation easy? Or the size and weight is portable? Is it attachable and detachable?
Function	Communication method, security, expansibility, and other functions such as fax, Internet and navigation need to be considered.
Motion environment	Due to the particular environment of a container terminal, the motion environment including temperature, humidity, vibration, and waterproof needs to be considered.

In case of PDA, web pad and DSRC, they have a problem in terms of cost and communication method. In case of HUD, which is now under development, it also has a problem in terms of cost, supply, maintenance and repair. And those were excluded. In case of mobile phone, it is cheaper, compared with other alternatives, but because of its limitation on communication and function, it also was excluded. Finally, the smart card was selected as an optimal digital media. The smart card satisfied all the demands in terms of cost, convenience, function, and motion environment, but for the realization of its system, such factors as size and external interface have to be customized. To this end, the smart card has been redesigned so that it may be suitable to a non-stop automated gate system.

B. Definition of Job Order Information

In order to define data of the job order information needed to be transmitted to the digital media, we analyzed the current paper documents used for job order information. The major data in the job order information can be divided into five categories: general information, truck information, container information, yard information, and other information. In order to send this information to the digital media, text alone can be used or text plus other forms such as figure and symbol can be used together. Also, the information can be grouped into two: basic information and additional information. The definition of these data is in Table 4.

Table 4. The main data in job order information

Section	General information	Truck information	Container information	Yard information	Other information
Major data	Arrival time and date	Truck No.	Container No.	Input/output	Company name
	Slip No.		Container size	Yard location	Company logo
	EIR No.		Container weight	TC No.	Yard map
	Gate Lane		Full/Empty		Cautions
	Gate worker		Seal No.		Container picture
			Container damage		Chassis No.
			Damage code		
			Freezing temperature		
			IMDG		

In order to receive job order information without stopping a truck, it has to be transmitted to the digital media in the truck. This data transmission is required to meet both the characteristics (memory, screen size, etc.) of a digital media device and user's demand. Also, its display format has to be easy for truck drivers to read. The basic data to be transmitted to the digital media are shown in Table 5. They are displayed in the sequence of job order information, recognition information, and other information.

C. Design of Digital Media

A smart card was selected as the digital media for job order transmission, and the data to be delivered to the digital media was defined. To make these data easy to read and to make it easy and convenient to handle the digital media, this study introduced the ergonomics guidelines to the design of this digital media. For digital media design, the following user's demands and ergonomics guidelines were adopted.

- User's Demands

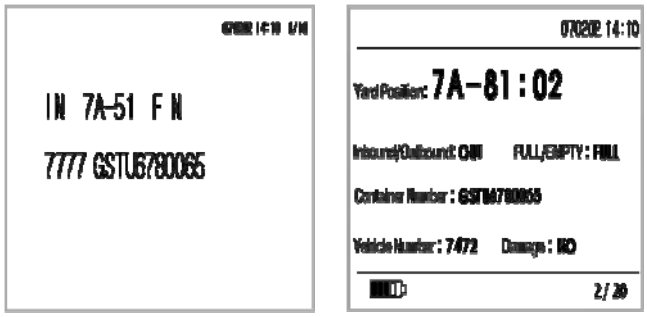
- Basic and additional information services
- Linkage to the legacy system
- Suitability to terminal environments (temperature, humidity, wind and impact)

Table 5. Basic data transmitted to digital media

Information		Contents
Job order	Location	Yard location of container ex) 7A-81:02
	In/Out	Gate in/out of container ex) In/Out
	Full/Empty	Whether truck has container or not at gate ex) Full/Empty
	Error code	When error happens, display messages
Recognition	Container No.	Container no. of gate in/out ex) GSTU 678006
	Truck No.	Truck's plate no. of gate in/out ex) XXXX
Other	Damage of Container	Whether damage is or not ex) Yes/No
	Caution	ex) speed limit

- Data's reliability and security
- It should be easy to confirm the information
- It should be easy to buy the media device
- It should be easily attachable and detachable, and suitable to environment (temperature, humidity)

As a display method for the screen of digital media, the combination of a picture, symbol and letter is preferable. But because of the limitation of black/white dot LCD display, letters alone have to be used. So, we tried to deliver an accurate meaning of each data by using the regular data.



Early Data Output Screen Design

Applying Regular Data

Fig. 1. Example of screen for digital media

In the screen of digital media, the size of letters should not be smaller than 2.6 mm, in case that the viewing distance is beyond 50 cm. Concerning stroke-width, white color background/ black figure needs 1: 8 (if the height of a letter is 0.8, its thickness is to be more than 0.1). In case of the width-height ratio, upper case is to range from 1: 1 to 3: 5, but figure is to be 3: 5. If the height of letter is "H," the letter's width should be from 0.5 to 0.8 H, the space between letters should be from 0.2 to 0.5 H, and the space between lines from 0.6 to 1.5 H. Concerning the readability of letter's group and figure's group, three or four letters or digits are easier to read.

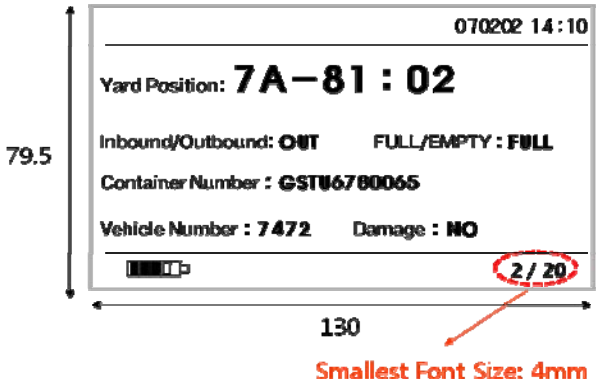


Fig. 2. Example of screen considering font size according to distance of sight

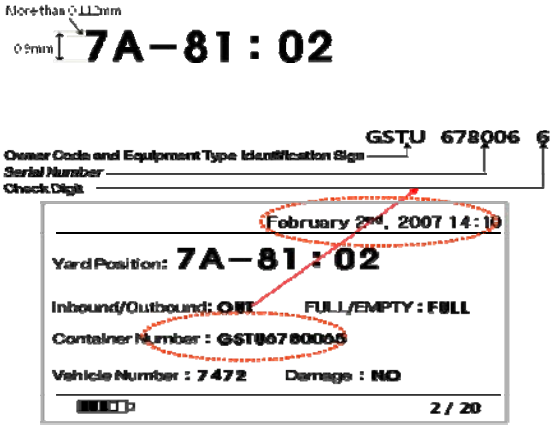
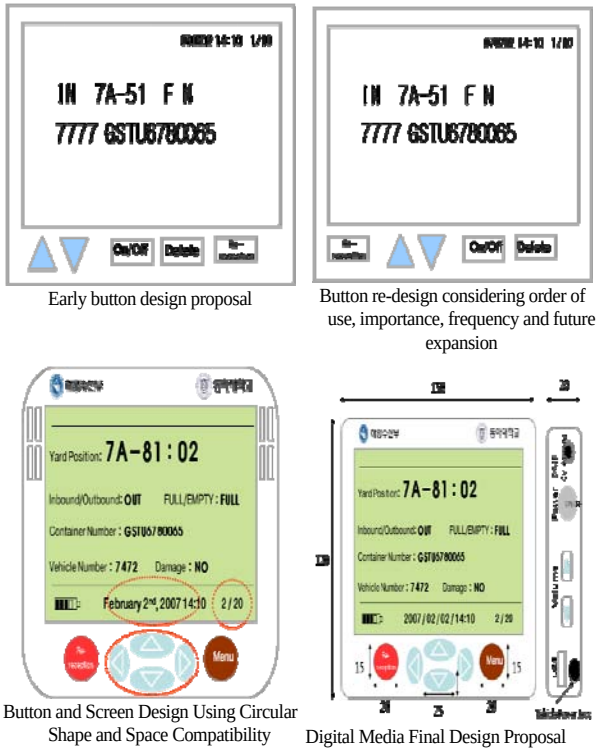


Fig. 3. Example of final screen

The external interface design of digital media has to take into consideration the following factors: parts layout, image, layout, function and sequence of use. As shown in Table 6, buttons layout was made according to the principles of importance, usage frequency, functional layout, and order of use. According to function and order of use, clear boundary marking was made between part's groups (button, LCD). Also, to minimize contact error frequency, the interval between control devices was made wide more than 2.5 cm.

Table 6. The function and importance of buttons on digital media

Button Type	Importance	Usage Frequency	Function
Receive	High	Middle	Receiving request again
Upper and lower button	Middle	Middle	Cursor move
Left and right button	Middle	Low	Cursor move
Menu button	Low	Low	Menu calling
On and off button	Low	Low	On and off



Early button design proposal

Button re-design considering order of use, importance, frequency and future expansion

Button and Screen Design Using Circular Shape and Space Compatibility

Digital Media Final Design Proposal

Fig. 4. The final design of digital media

After designing the external interface and screen, digital media is required to be attached to the trucks, and will be used by drivers. Therefore, the location of this digital media device should be decided according to user's visual aspect. If a driver gives his eyes to the digital media device 15 degrees below the horizontal line, and if the device is in an oval with a radius of 10 – 15 degrees like Fig. 5, this location is good for reading and eye contact.

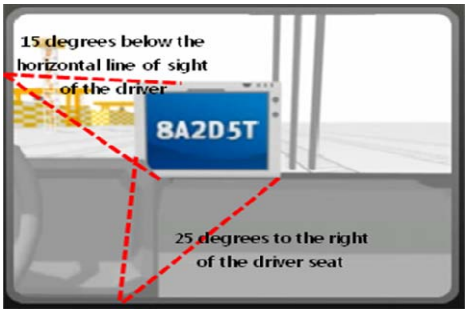


Fig. 5. The installation location of digital media in a truck

IV. Development of Non-stop Automated Gate System

A. Gate In/Out Process at the Non-stop Automated Gate

If digital media is used at the gate, a container truck does not need to stop at the gate to take a slip. The gate in/out process at the non-stop automated gate is shown in Fig. 6 and 7.

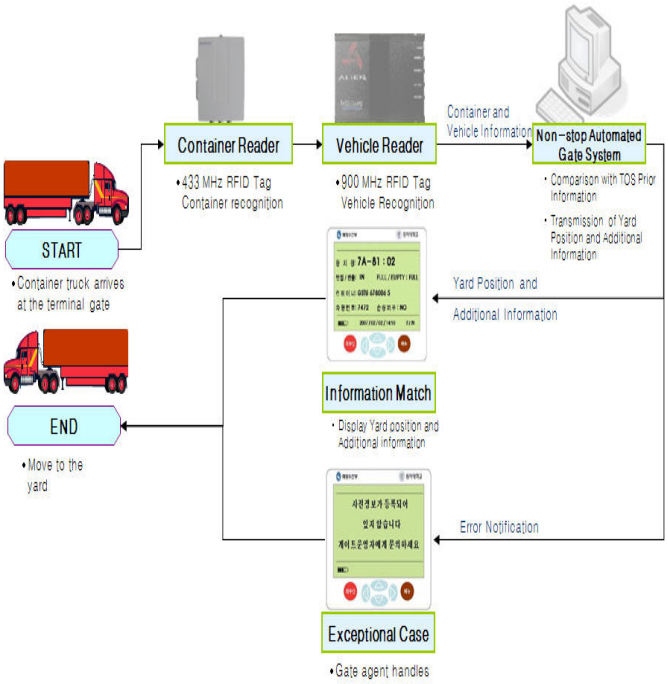


Fig. 6. Gate in process at the non-stop automated gate system

In case of gate in of a container, a container truck arrives at the gate, and the 900 MHz RFID tag attached to the container truck has information on the truck. Also a 433 MHz tag, which contains information on the container and its contents, is attached to the truck's container. An RFID reader recognizes this information, and compares with COPINO. If this information corresponds to the COPINO, it prepares job order information and transmits it to the digital media. According to this information, the truck driver moves to the appointed location of the yard and stacks the container. However, if the information does not correspond to the COPINO, it will send an error message, and the gate worker will take a necessary measures.

In case of gate out of a container, an RFID reader recognizes the RFID tag attached to the container truck. And this truck receives the job order information via the digital media, and moves to the yard where the corresponding container is located. After loading the container, the container truck moves to the gate. At the gate, the information recognized by an RFID reader is required to be compared with COPINO. If it is consistent with the COPINO, the container truck will pass the gate and finalize the gate out of container. But if it is not consistent with the COPINO, the gate worker is to send an error message, and a necessary step has to be taken.

B. The Configuration of Non-stop Automated Gate System

As shown in Fig. 8, a non-stop automated gate system is composed of an RFID-based recognition system and a digital media-based information transmission system. RFID devices consist of an RFID reader and an antenna for the recognition of trucks and containers. Digital media consists of an information

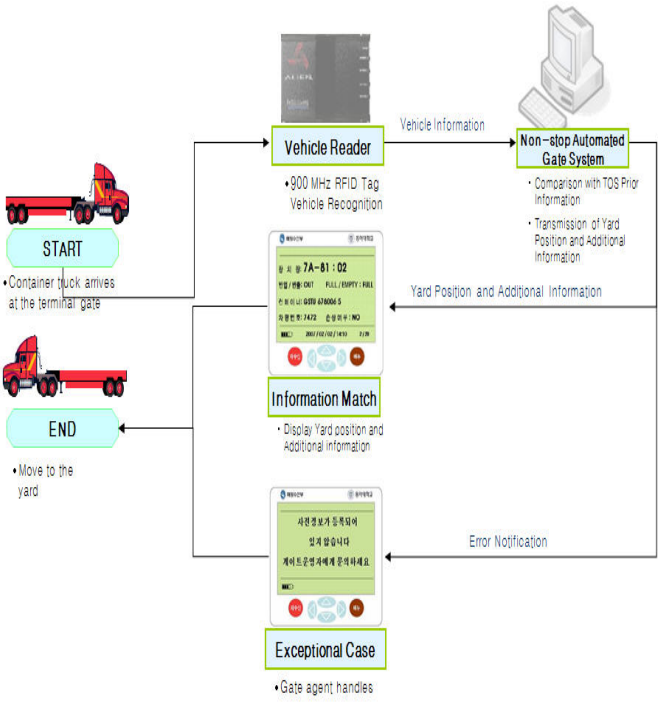


Fig. 7. Gate out process at the non-stop automated gate system

transceiver and a terminal. Owing to the characteristics of RFID technology, the recognition ratio of each device is significantly affected by its attachment location. For this reason, as shown in Fig. 9, the tag and antenna have been attached to the optimal places in order to improve the ratio of recognition [2]. The electric bulletin board and signal lamp are to be used as an auxiliary device when a problem has happened with a non-stop automated gate system. These devices are attached to the entrance of the gate so that it may be easily recognized when the truck driver passes the gate.

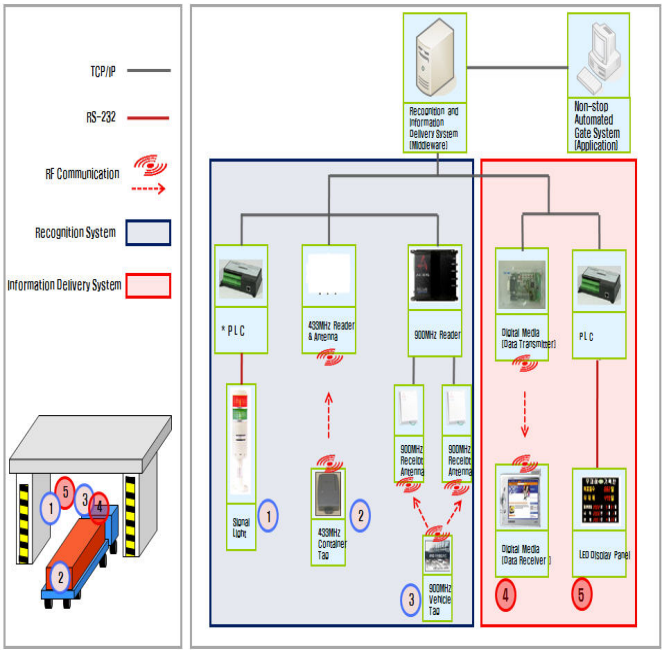


Fig. 8. Configuration of non-stop automated gate system

By using TCP/IP, RS-232 and RF communication method, RFID devices and digital media is to communicate with a recognition system, information transmission system, and non-stop automated gate system. According to the standard rules on frequency usage, this study used RFID 900 MHz for truck recognition and RFID 433 MHz for container recognition. In case of a digital media-based information transmission system, RFID 2.45 GHz frequency was used for communication between a transceiver and a truck's digital media. The frequency used for a truck and a container is different. The reason is to reduce interference between two frequencies, so that it may not lower the recognition ratio of digital media.

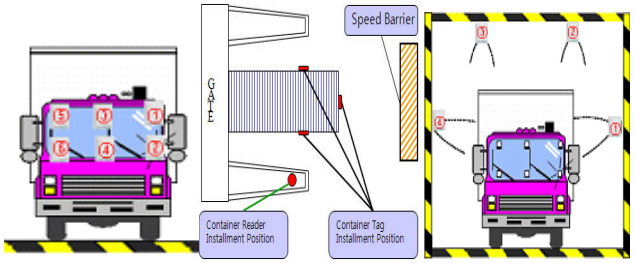


Fig. 9. RFID truck tag's location for optimal recognition/ RFID container tag's location for optimal recognition/Antenna's location for optimal recognition of RFID tag

All the data are to be filtered both in the recognition system and information transmission system, and only effective data will be transmitted via socket communication to the non-stop automated gate system. The non-stop automated gate system compares the data from each middleware with COPINO coming from the TOS and then performs its jobs. Also, it sends the results of its work to the TOS, so that they will be used for the operation of the whole container terminal. In addition, for linkage with a legacy system and for construction of a new system such as ACDI, this study designed middleware and communication channel for mutual communications between the systems.

C. Development of Non-stop Automated Gate System

Non-stop automated gate system performs the function of managing information coming from both RFID recognition devices and digital media information transmission devices. It also recognizes the truck's plate number and container number at the gate in order to perform the function of transmitting the job order information. Non-stop automated gate system is composed of a basic information management module and a gate-monitoring module. The detailed functions of each module are shown in Table 7.

As shown in Fig. 10, the basic information management module consists of user management, COPINO management, and devices management. User management deals with the information on managers and users. COPINO management is required for comparison with the information coming from

RFID recognition system. Devices management deals with registration of all the devices including RFID reader, antenna, information transceiver, and electric bulletin board, and it also performs the function of suspending and restarting the related devices for the solution of problems.

Table 7. The composition of non-stop automated gate system

Section	Detailed Function	Remarks
Basic information management	User management	Registration, modification, and deletion of application user information
	COPINO Management	Registration, modification, and deletion of COPINO information for comparison with recognized information
	Devices management	Registration, suspension, restarting, and deletion of RFID recognition devices and digital media information transmission devices
Gate monitoring	Truck in/out management	Confirmation, registration, and deletion of truck in/out information
	Container in/out management	Confirmation, registration, and deletion of container in/out information
	Job order information Management	Confirmation, registration, and deletion of job order information
	Errors management	Confirmation, registration, and deletion of errors that happen in the process of container in/ out

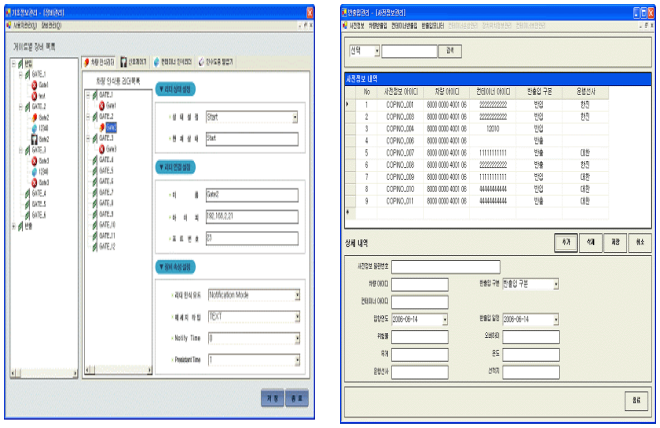


Fig. 10. Interface for basic information management

As shown in Fig. 11, the gate-monitoring module performs the function of monitoring all the trucks and containers' gate in/out, job order information, and errors. The monitoring module makes it possible to confirm, on a real time basis, the information on all the gate in/out of trucks and containers and also to check whether the digital media devices are well receiving the job order information or not. If the recognized information is not consistent with COPINO, or if the job order information is not delivered correctly via the digital media devices, the error message is issued. This error message will help the gate worker to perform his job correctly.

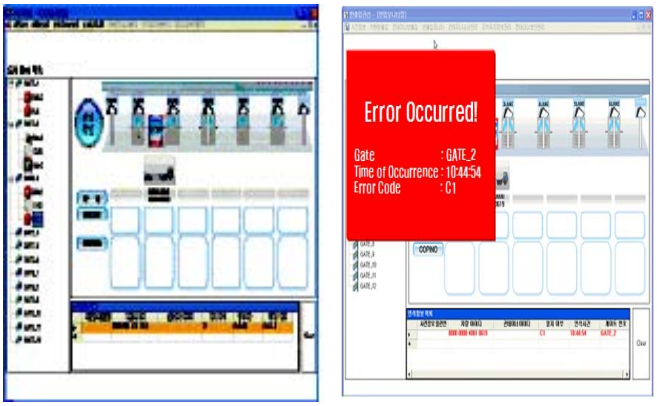


Fig. 11. Interface for gate monitoring

D. Tests and Expectations

To test the new non-stop automated gate system developed in this study, the following three scenarios have been performed in the P container terminal in Busan: first, when one truck enters the one lane of the gate, secondly, when more than two trucks enter the one lane of the gate and finally, when more than two trucks enter the two lanes of the gate on a random basis. Each scenario has been tested 50 times. The purpose of these tests is to measure the recognition rate, data transmission reliability and required time of gate-in/out of the RFID tags and digital media devices, and to find out the problems that can happen in the future. As a result of these tests, each scenario has shown the 100% recognition rate and reception in transmitting work order information to the truck tag, to the container tag and to the digital media terminal. Also, the data such as truck number, container number and digital media serial number has transmitted 100% perfectly to RFID-based recognition system, digital media-based information delivery system and non-stop automated gate system. In addition, when checking inbound and outbound cargo trucks, the existing bar code has on the average taken 30 seconds for passing the gate, but this system takes nearly no time. However, since this is the result of pilot tests, the validity of this study will be proved in the field tests.

In order to check the economic benefits of digital media system and to compare it with the existing bar code, we have made a survey of 40 container terminals in Korea (including the terminals to be built in the near future) in terms of introductory costs and operating costs. We have assumed that the price of digital media terminal is US$ 53, its useful life is 3 years, the number of container trucks is 25,000 units and annual cargo handling volume is 15,000 TEU. The results of the survey have revealed that the introductory costs of digital media is 2.5 times higher than that of bar code, but the operating costs are only

40% of the latter because of labor cost saving in terms of slip issuance and repair and maintenance (refer to fig. 12). If the digital media terminal could be bought at US $50 level, the initial investment cost will be recovered in three years of its useful life.

The productivity improvement coming from reduced truck congestion and shortened truck stop hours by virtue of the introduction of non-stop gate system has not been contained in the costs accounting. Therefore, considering this improvement, much more benefits are expected from the new system.

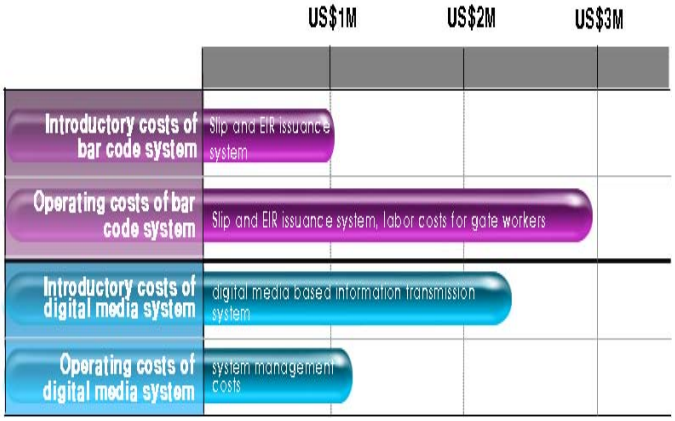


Fig. 12. Comparison of bar code system and non-stop gate system in terms of introductory costs and operating costs for three years

V. Conclusion

At present, the bar code system and OCR gate system now in operation are meeting with a low recognition rate and long handling time. In an effort to solve these problems, the RFID based automated gate system has been introduced, but the non-stop automation of the whole gate jobs has not yet completed. For this reason, this study tried to combine the RFID technology and digital media technology and succeeded in designing and developing a non-stop automated gate system. From now on, in order to enhance the productivity and efficiency of container terminal gate, more researches have to be made for non-stop automation of container cargo inspection and container weight confirmation. Meanwhile, this study on U-port will lead to yard management, warehouse management, and berth management.

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