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A Development of Integrated Operation System of Container Terminals in Ubiquitous Environment using RFID

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Abstract : *Number of researches on efficient terminal operation system applying RFID(Radio Frequency Identification) are in progress. However, RFID has limitations on tracking and providing accurate positions of containers. In this paper, to enhance the performance of the integrated terminal operation system, an efficient loading management of yard is proposed by applying RFID based RTLS(Real Time Locating System) that provides real time accurate positions of containers. It was found that a group based sequence system is more efficient than the existing individual sequence number system in the container yard. In the group based sequence system, the containers in the same group should have similar characteristics such as port of destination(POD), size, weight, etc. In order to run this system, we proposed the parameters to the unspecified N bytes of RFID tag which are specified in ISO 18000 7. And then, we developed an integrated operation system of container terminal using RFID. The proposed system reduces the ship turnaround time in ubiquitous port environments.*

Key words : *RFID, RTLS, Ubiquitous port, Operation system, Twin lift gantry crane, Container terminal*

1. Introduction

Shipping lines consider the ship turnaround time as a critical factor when selecting a calling port for reducing costs. The congestion of port logistics due to the insufficient of the port facilities is getting worse because of the trend of the super mega vessel and speedy delivery. And, the reduction of the calling port by shipping companies is hard to be managed for each port. The terminal operator has to improve the quality of service in the port in order to become a hub port. In order to do that, the ship turnaround time should be reduced through investing in the port facilities as an incentive policy. To enhance the loading productivity, the adoption of a new port loading equipments is required Drewry(2003).

Many researchers have been studying the optimization of pre-planning and high-performance of the Gantry Cranes (GCs) in container terminals for faster loading and unloading Choi (2004).

The research on an efficient terminal operation system applying RFID(Radio Frequency Identification) is common nowadays. However, RFID has limitations on tracking and providing accurate positions of containers. In this paper, in order to enhance the performance of the integrated terminal operation system, an efficient loading management of yard is proposed by applying RFID-based RTLS(Real Time Location System) that provides real-time accurate positions of containers. This paper have proposed the parameters to the unspecified N bytes of RFID tag which are specified in ISO 18000-7(ISO/IEC 18000-1), and developed integrated operation system of container terminal using RFID for reducing the ship turnaround time in ubiquitous port environment.

2. Previous Works

Some of the advanced ports installed which utilize the RFID and other communication system technologies have better competitiveness to the lagged ports. There are some researches adopting RFID and the wireless network technologies for faster speed, more secured, and support automated work procedure in the logistics infrastructure. Especially, RFID at 433MHz can trace container's data from the long distance about 100m in real-time.

But it also has a microscopic awareness function sensing humidity or damage in the containers. This technology is nowadays adopted and utilized in U.S and England armies for reinforcing fast and secured procurement of military supplies.

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Current RFID technology is known as it has limitation to read precise position in busy areas like container yard and container berth, in which a number of RFID tags are congested.

For this reason, loading and discharging works at container yard and quayside have been excluded in the scope of project of 'RFID Efficiency and Performance in Port Logistics' organized by Korean Maritime Affairs and Fisheries Office, and even same cases in SST, APEC STAR-BEST Project, APL Projects [4].

2.1 SST (Smart & Secured Trade Lane)

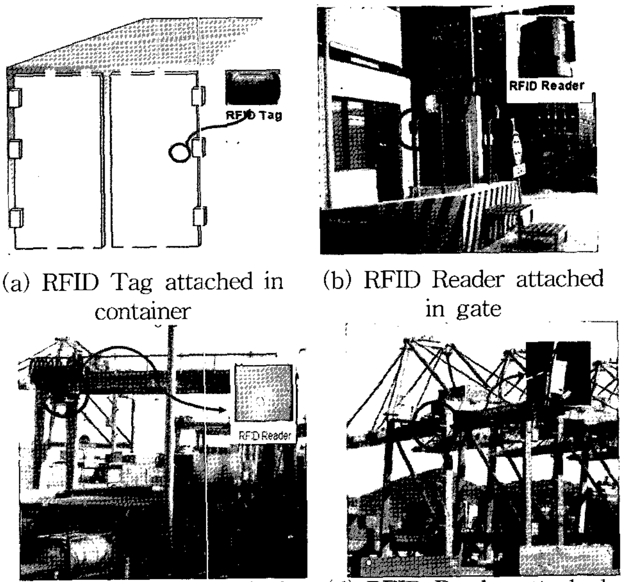
As International Trade Organization requests more strict security in cargo transactions since 9.11 tragedies, not to mention about the security in shipping and port, it is now mandatory to every cargo imported/exported via ocean. In United States, the Ministry of National Defense & Security is supporting 'Smart & Secured Trade-Lane Program' through the whole channel of port, shipping, Consignor. For instance, HPH, PSA, P&O Ports, which are 3 major terminal operators in the world having more than sixty percent of worldwide container cargo handling, have involved in this project, in co-operation with their sixty five global partners, twenty stevedoring companies and twelve solution providers. It reaches eighty five percent of container cargo operation in U.S.

2.2 APEC's STAR BEST Project

Asia Pacific Economic Committee (APEC) has implemented a supply network security system named 'STAR-BEST' in 2003 as a pilot project for the purpose of marine cargo security. STAR-BEST project implemented an end-to-end supply chain solution using RFID technology and electronic seals to track secure containers from points of origin in Thailand to distribution centers in Seattle and Washington, using the data from this demonstration project and similar initiatives.

2.3 RFID Efficiency and Performance in Port Logistics

Fig. 1 shows the configuration of container terminal using RFID as a result of the Korean Maritime Affairs and Fisheries Office's project called 'RFID Efficiency and Performance in Port Logistics'. The project enhances the existing operation system to improve the efficiency of the entire work in ports. Fig. 1(a) shows the position of an RFID tag attached to a container box. Fig. 1(b) shows the position of an RFID tag in gate. The purpose of the project is to construct an infra that can handle non-stop gate in/out operation with RFID system by replacing the existing barcode system.



(a) RFID Tag attached in container
(b) RFID Reader attached in gate
(c) RFID Reader attached in TC
(d) RFID Reader attached in GC

Fig. 1 Configuration of RFID System in Container Terminals

Fig. 1(c) shows the improvement of the yard productivity. First, the container is placed by the information of the container box automatically obtained from an RFID tag by TC(Transfer Crane) reader. The work productivity will be enhanced because of the prevention of erroneous typing and simplicity of the procedure through the automatic recognition. Fig. 1(d) shows the improvements of loading productivity. The process of a GC shown in Fig. 1(d) is same as the TC shown in Fig. 1(c)[5].

As a matter of fact, currently developed 433MHz RFID has some limitations to read and trace the accurate position of each container tag in the congested area. It says that RFID reader can read the existence of tag within certain distance, but, unable to catch up each container's precise position in real-time.

3. Development of Integrated Operation System of Container Terminals using RFID

3.1 Concept of RFID based RTLS

RTLS is RFID-upgraded to produce instant location information. Items tagged with normal RFID are read when a reader is brought near a tag or a tagged item is passed near a reader. RTLS allows a reader unit to "see" the actual location of a tagged item, without being near the reader, using special readers placed around a property, tags are located using a triangulation system. RTLS could recognize location, access and movement of tagged objects because of the characteristics of electric wave in the wireless environment. In the range of realization, it has been called as local GPS(Global Location System), and it is used especially in the smallest area. For example, RTLS is used to find specific things, people and give additional services in an indoor area such as facilities and offices as well as limited outdoor area. The objective of RTLS technology is real-time locating service in the world as global GPS [6]. Now, RTLS is used with Wi-Fi technology which is used in wireless-LAN, but there is a serious trend to introduce the next generation technology such as UWB(Ultra-Wideband) and ZigBee [7].

RTLS is divided into two scopes according to the frequency. ISO 24730-2 is operated in 2.4GHz and ISO 24730-3, which is for port logistics, and operated in 433GHz. RTLS track location and estimates distance by trigonometry method with RSSI(Received Signal Strength Indicator) and TODA(Time Difference of Arrival) technology.

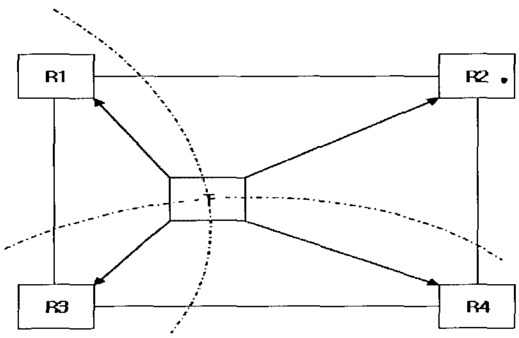


Fig. 2 The method of location survey by TDOA

Location survey by TDOA system is shown in Fig. 2. Time difference among signals from each reader R1, R2, R3 and R4, can estimate the distance from reader to tags. It can derive the small oval area, and then the intersection of these ovals is the location of the tag. In the case of RSSI system, it estimates the distance by relative decrement of signals. RTLS can estimate the distance by tags and signals.

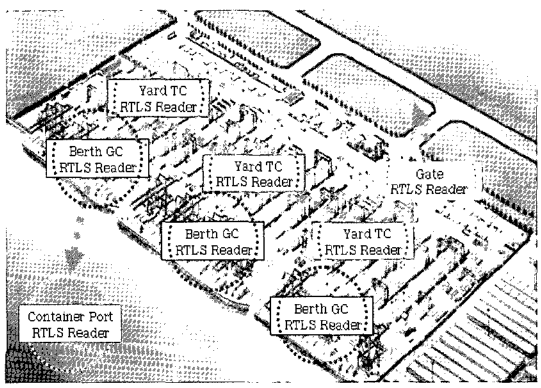


Fig. 3 Container terminal using RFID-based RTLS

The Fig. 3 shows container terminal using RFID-based RTLS system.

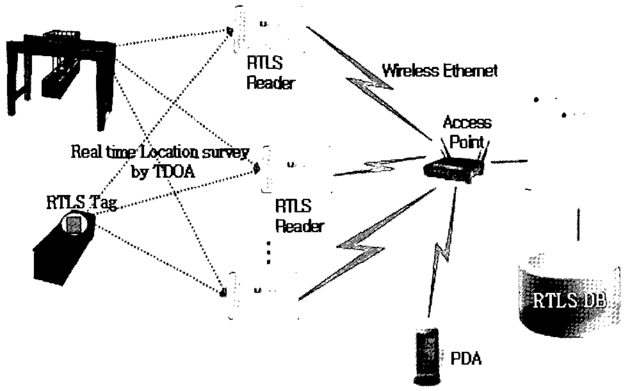


Fig. 4 RFID-based RTLS configuration

The RTLS is to provide regular position information of tagged assets within a facility. A facility could be outdoors, as with truck depots, or indoors, as with container terminals. RTLS allows a reader unit to "see" the actual location of a tagged item, without the tagged item being near the reader. We formally describe RFID-based RTLS configuration as shown in Fig. 4. RTLS readers are usually deployed as a matrix of readers that are installed at a spacing of anywhere from 50 to 1,000Ft [8].

3.2 RFID based RTLS tag message format

The RFID standardization is to prescribe wireless interface or protocol so that its tag and reader are able to translate and communicate data and information. It is in process as ISO 18000 series by ISO, and JTC1-SC31 WG4 SG3 joint technology research of IEC[9].

The basic function of RFID technology is to recognize the existence of objects. Usually RFID application's services on the basic of logistics deal with lots of goods. Passive tag has been developed to alternate Barcode. To transmit the information of real time location, a tag needs to make signal by itself and transmit the information actively.

The RTLS physical layer(PHY) accepts service data units (SDU) from higher layers for transmission onto the orthogonal frequency division multiplexing (OFDM) physical medium. The RTLS physical layer specification provides location awareness and operates in the 433 MHz band. There are mechanisms in this physical layer specification that facilitate the development of semiconductor devices and infrastructure, which is backwards compatible with ISO 18000-7 RFID tags [10].

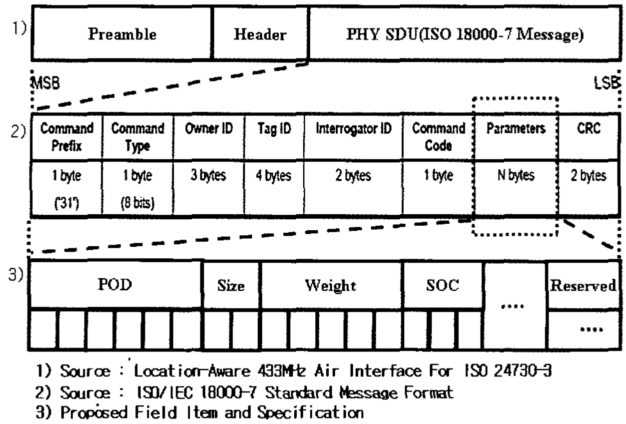


Fig. 5 Proposed RFID-based RTLS tag message format

The suggested method in this paper used the way which is developed by the Savi in USA. The first reason of using RFID tag is a security of ports in USA against inbound cargoes since 9.11. RTLS makes the port more efficient. However, in the places of shipping companies and shippers, they are not willing to pay for the expensive RTLS.

Therefore, we define the parameters in the parameter field for the efficient port operation onto the Savi's RFID tag implemented in the RTLS. Fig. 5 shows location-aware 433 MHz air interface for ISO 24730-3's RTLS PHY SDU by the Savi [11].

Table 1 shows our suggested field item and specification for the N Byte's Parameters.

Table 1 Suggested message field item and specification

Suggested field item	Bit		Specification
POD	6		Supports 64 of main ports
Size	2		Supports 20, 40, 45Ft
Weight	5		Supports 32 classes of weight
SOC	3	000	Normal Cargo - Load Cargo
		001	Normal Cargo - Empty Cargo
		010	Dangerous Cargo
		011	Reefer Cargo
		1xx	Reserved field

3.3 A Proposed of integrated operation system of container terminals using RFID

1) Existing operation system of container terminals

The terminal operating system consists of three components such as GC, TC, and YT(Yard Tractor), and they are inter-related. For imports operation, the GC unloads containers from a vessel onto an YT. Then the YT transports the containers to the TC. Finally the TC unloads the containers to the yard. For the exports, the operation proceeds opposite direction and procedure.

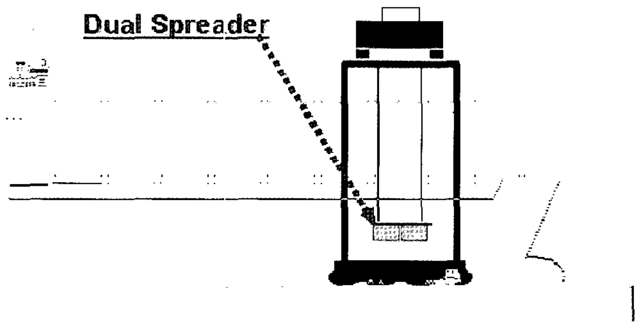


Fig. 6 Twin-lift using Dual-Spreader

The Fig. 6 is shown Twin-lift using Dual-Spreader. Twin-lift using a dual spreader loads 20Ft containers at the same time. This facility reduces the round time of YT to the yard, as well as the loading/unloading process of GC by half. Twin Dispatch reduces the turning time at YT.

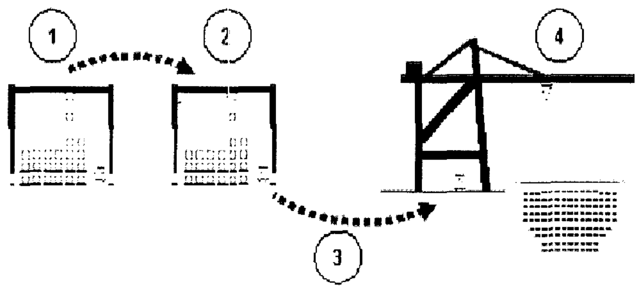


Fig. 7 Twin dispatch allocation

Fig. 7 is shows Twin-dispatch at yard. Twin dispatch reduces the turning time at YT. At first, if there is only one to load at the first TC, then the YT moves to the next TC for the second container, since the YT has capacity of two containers. The YT contained the two 20ft containers moves to the GC. Then the GC loads the containers loaded in the YT with the twin lift. At this point, if the other container has different port of destination, then the YT moves to the other GC for the container [12].

Table 2 shows an analysis of the existing container loading and unloading procedures Kim(2002).

Table 2 Analysis of the existing container loading and unloading procedures

Step 1 : Pre-marshaling stage

1.1 The plan of operation procedure by the Stowage Plan in the port planner center.
1.2 Transfer the stowage Plan to Shipping Companies
1.3 Transfer the container operation sequence to the TC driver on the yard.

Step 2 : Twin dispatch container loading stage at yard

2.1. TC Driver load container onto YT according to the individual sequence number system
- The decrease of the TC productivity as the increase of the re-handling by container operation procedures.
- The increase of the YT cycle time due to increase of TC waiting time with re-handling of TC
- Increasing cycle time of YT reduces GC productivity. In case of the twin-lift operation, YT waiting time increases as re-handling by TC increases

2.2. After finishing the loading container on the YT, TC driver transfer the completion message to port planner center by touch screen computer
- The increase of the operation time by the hand work of the TC driver.

Step 3 : Tally Stage at berth

3.1. Tally man from shipping company check the working sequence by container number in the stowage plan
- The loading operation is not operated because of the safety reason when the operation sequence is out of order
- Loading operation is possible after the verification of the port planner center when the sequence is out of order

3.2. Transfer data for checking up work after cargo are loaded by GC
- In the case of the work of twin-lifts, safety concerns are remained according to skill of GC driver
- Increasing of working time due to transferring data to the central server after operation using the touch screen computer

2) A Proposed Integrated operation system of container terminal using RFID

An efficient dispatching algorithm for twin-lifting in GC which is suggested in this paper is shown in Fig. 8. The suggested integrated operation system of container terminal using RFID-based RTLS supports twin-lift operation more efficiently in ubiquitous port environment. The proposed RFID-based RTLS tags read and inform real time messages to the monitor in the TC.

In the yard, the RTLS Reader recognizes the information of RTLS Tag shown in Fig. 5. Firstly, it sorts the container boxes with information such as the POD, the size, weight. Then it classifies them by the groups of containers such as SOC(Danger Cargo, Reefer Cargo, and FCL). Since the suggested system operates with a group based loading sequence, the workload of re-handling in TC is reduced.

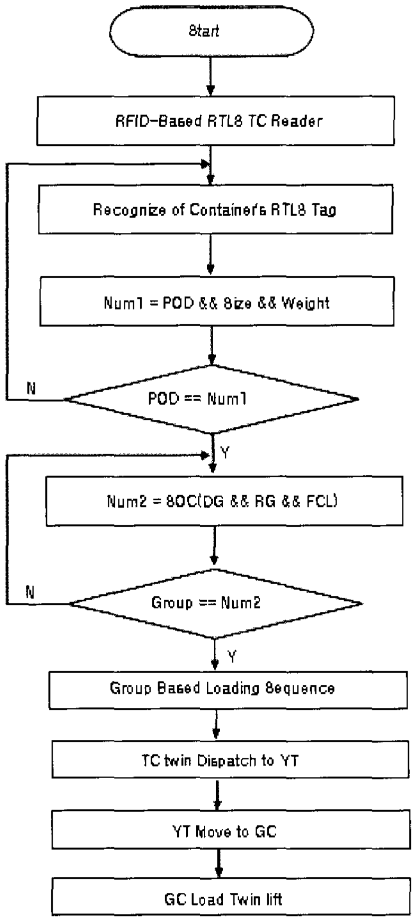


Fig. 8 A flowchart describes efficient dispatching algorithm using RFID-based RTLS

Table 3 shows an analysis of proposed integrated operation system container loading and unloading procedures using RFID.

Table 3 Analysis of proposed integrated operation system container loading and unloading procedures using RFID

Step 1: Pre-marshaling stage

Step 2: Twin dispatch container loading stage at yard

2.1 TC Driver load container onto YT according to the group-based sequence number system
- Increasing productivity of TC due to the reducing of re-handling as using the group operation
- Decreasing YT waiting time as the TC re-operation decreases

- The productivity of the GC increases as the total cycle time of YT decreases
- Additional waiting time is decreasing as the decrease of the re-handling of TC where the operation uses the efficient group-based twin-lift method

2.2 After finishing operation of YT, TC driver check up the completion by RTLS server in port planner center
- Data is transferred automatically to the main server by RTLS reader

Step 3 : Tally Stage at berth

3.1 The main server transmits the sequence of the container's operation in real time to the tallyman's PDA

3.2 The tallyman from the shipping company checks up the operation sequence through the PDA in real-time
- The RTLS system with wireless communication makes the verification time reduced

3.3 After the loading operation of the GC, GC driver transfers working confirmation to the main server
- The safety accidents are reduced during twin-lift operation with RTLS tag
- After finishing all operations, completion message is transferred automatically to Main server - reduce the time and prevent errors

4. Performance Evaluation

In order to evaluate how the suggested RFID-based RTLS help improve working efficiency and performance, the computation_simulation was carried. Rockwell Software ARENA version 9.0 has been used for a modeling program.

4.1 The parameters for simulation

In order to evaluate how the suggested integrated operation system can help the improvement of working efficiency and performance, simulation has been conducted. Rockwell Software ARENA version 9.0 was used for modeling terminal. The constraint conditions for simulation are as following Table 4.

The simulation does not consider other factors listed constraints for the container port. The parameters for simulation are as following Table 5~Table 7 (Mark et al.(2002); Michael et al.(2002)).

Table 4 Constraint conditions

1. Initial pre-planned yard allocation is based on current algorithm and container loading is to be sequenced according to each group by POD, container size, weight, etc.
2. The necessary number of group and its container number in each group for simulation are to be referred by provided EDI information from shipping company.
3. A simulation is performed by considering the relationship of GC, YT, and TC
4. Quayside length : 1,050m
5. Terminal operation time : 23h/day
6. M/M/S Queue theory is used for simulating the productivity of our suggested method

Table 5 Size of vessels, LPC, and number of GC

Size of Vessels	Average LPC	Number of GC
Super-mega vessel	2,000	5
Mega vessel	1,500	4
Middle vessel	800	3
Small vessel	300	2

Table 6 Throughput of GC

Type of GC	Loading productivity of GC	
Single hoist GC	Mechanical throughput	45Van/h
	Average throughput	30Van/h
Twin-lift GC	Mechanical throughput	60Van/h
	Average throughput	34Van/h

The difference between mechanical throughput of single hoist GC and the average throughput is the delay of TC operation and the lack of the number of the YTs. The higher the usage of the twin-lift GC, it makes the higher the average throughput for 20ft containers.

Table 7 Driving speed of YT and average movement distance

Classification	Productivity of YT
Average driving speed	20Km/h
Average movement distance	1,500m
Waiting time at TC and GC	2min
Loading time at GC	2min
Loading time at TC	2min

4.2 Results

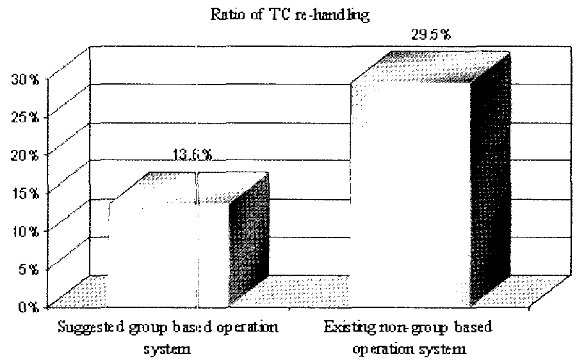


Fig. 9 Ratio of TC re-handling

The simulation has been performed with 300 boxes of TC work load and the gate-in numbers of containers are set to 15 boxes. When 315 boxes are loaded by GC, the operation of 408 times is occurred and needed 29.5% re-handling at the current yard as shown in Fig. 9. The suggested group based operation system is applied to TC, another 13.6% of re-handling occurs. So it is improved about 16% of re-handling. Work group bases reduce the TC's re-handling during dispatching for twin lifting in GC with the proposed method.

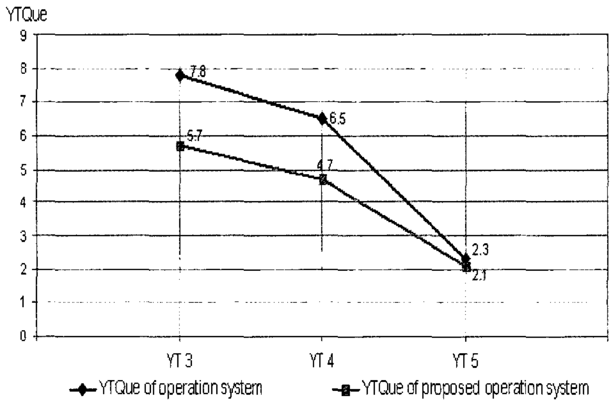


Fig. 10 YTQue size of proposed integrated operation system

The proposed integrated operation system using RFID shows better performance than the exiting method as shown in Fig. 10. The higher the number of the queue size of YT (YTQue) means that there are more waiting containers at GC or TC. Therefore, the proposed method shows better performance since it has lower number of YTQue size than that of existing one. We assume the one of GC is fixed at 30Van per hour, and the TC works in real time when YT arrives. In this experiment, a single GC handles with 3,000Vans. The proposed algorithm versus the existing method enhanced 2.1 points, since they have 5.7 and 7.8 for each when YT is 3.

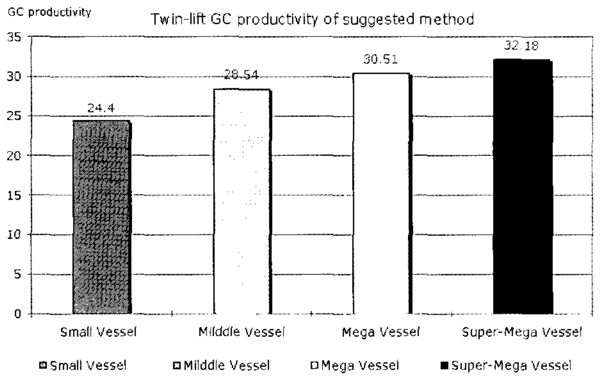


Fig. 11 Twin-lift GC Productivity of suggested method

Fig. 11 shows ship turnaround time and loading/ unloading productivity applying the suggested integrated operation system using RFID. The simulation is set not to an interference effects caused by YT. As a result of GC productivity simulation, the productivity applied the suggested method of twin-lift GC showed the best performance of all. The suggested method with Twin-lift GC saves turnaround time comparing to single hoist GC. The small vessel and the super mega vessel save 58 minutes and about 3hours respectively. Also, a super mega vessel using the suggested method showed better performance than the small one.

Therefore, the suggested method is evaluated as a proper technology to the bigger trend of container vessels.

5. Conclusion

This paper proposes integrated operation system using RFID-based RTLS for container terminal and its efficiency to enhance the performance of terminal operation system. It showed better performance when there is more volume than less volume.

In the group-based sequence system, the containers in the same group should have the similar characteristics such as port of destination, size, weight, etc. In order to run this system, we have proposed the parameters to the unspecified N bytes of RFID-based RTLS tag specified in ISO 18000-7. And, this paper proposed a development of integrated operation system of container terminal using RFID for reducing the ship turnaround time in ubiquitous port environment. Therefore we expect that a container terminal adopting our suggested system would have the superior reputation in this business.

This research should be further developed and studied on the parameters of the container terminals to reinforce RFID tag field for the efficiency. Other parameters proposed in this paper should be considered for the next research. Secondly, the middleware supporting the suggested tag format in this paper also need to be studied. Thirdly, the modeling of the twin-lift system should be experimented with detail descriptions and parameters for the various situations in the ubiquitous port environment. Finally, the information applied for the advent of the next super mega container for remodeling port is requested such as estimation of required number of GC, YT, and TC.

To construct and revitalize the port operation system based RFID. The prior promote container ports should be selected in according to current technology states, and they have to be propelled with the circumstance and standardization tendency in intra-national and international.

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