A STUDY OF YARD TRUCK DYNAMIC PLANNING AT A CONTAINER TERMINAL

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ABSTRACT

At a container terminal, a set of yard trucks (YTs) is usually assigned to a specific quay crane (QC) until the work is completed. In this process, YTs return to the QC after delivering the containers. Containers are transported from the quay to the storage yard and vice versa by YTs, in which YTs are used for transfer operations. We focus on the operational management of the dynamic transfer equipment deployed between the quay and the container yard, during the container unloading/loading process at a given number of ships according to a previously planned berth schedule. These investigations address the issues such as the performance criteria and the model parameter to propose an operational method of YTs assigned to a QC based on real-time positioning and increases the terminal efficiency. Also, we are developing alternative simulation based approaches to current and improved models. Improved model based on real-time positioning transfer system looks as the most promising practical technique to support decisions for the YTs deployment problem. Numerical results and computational experiments are reported to evaluate a study on the improvement of the operation efficiency in Korea Container Terminal.

Keywords: dynamic planning system, yard truck, container terminal

INTRODUCTION

A container terminal is a complex system with various interrelated components. There are many complicated decisions that operators or planners have to make. The handling operations in container terminals include three types of operations: ship operations associated with ship-berth link, receiving/delivery operations for external trucks, and container handling and storage operations in a yard. Container ships are loaded and unloaded where containers are temporarily stored while awaiting a new journey. Inbound containers arrive by ship and quay cranes (QCs) transfers containers from ship to a yard truck (YT). The YT then delivers the inbound container to a yard crane (YC or TC) which may be a rubber tired gantry crane (RTGC) or rail mounted gantry crane (RMGC). The YC picks it off the YT which moves back to the QC to receive the next unloaded container. For the loading operation, the process is carried out in the opposite direction. This is indirect transfer systems where a YT delivers a container between the apron and the container yard. RTGCs or RMGCs transfer containers between yard trucks and yard stacks in the container yard.

We focus on the operational management of the dynamic YT deployed between the apron and the container yard, during the container unloading/loading process at a given number of ships according to a previously planned berth schedule. This methodology indicates how this approach can be successfully integrated in a simulation model, already available, to support dynamic assignment of YT to allocated QCs. In such a model, the resource assignment, in terms of representation, allocation and management of the resources, plays a vital role regarding the efficiency of the whole dynamic YT deployment architecture.

Such a static assignment policy is also widely applied for container terminals. In order not to keep the QCs idle, a set of YTs continuously delivers containers to and from the assigned QC without interruption. Such a static assignment of YT is less flexible in its YT usage. To do this effectively, more YTs should be deployed especially when the ship is berthed far from its container yard. This can be a serious cost issue, especially if a set of YTs is permanently assigned to a specific QC as done at a dedicated terminal.

In the inefficiency lights involved in the static YT assignment, another approach may be more advantageous, such as: when a YT arrives at a container yard point in the yard after receiving a container from a QC under unloading operation, instead of going back to the QC which is situated far from the present location, it proceeds to the next stack point which is close to the present location, to receive a container for export, and then proceeds to another QC under loading operation. Such a dynamic YT planning may reduce the fleet size of YTs without increasing the overall dwell time of the ship in port, thereby minimizing unproductive empty travel (University of Seoul (2000)).

The YT assignment process is the allocation of handling tasks to container-handling equipment. Loading/unloading tasks are assigned to one of the QCs, based on the berth schedule and number of loading/unloading tasks for each ship. Transfer tasks are assigned to YCs dynamically, based on real-time information on waiting tasks and the status of each QC. This study is concerned with the dynamic planning system for YTs based on RFID/USN (radio frequency identification/ubiquitous sensor networks).

There are two types of strategies for assigning delivery tasks to YTs. One is a dedicated strategy and the other is a pooled strategy. In the case of the dedicated strategy, a group of YTs is assigned to a QC and deliver containers only for that QC. In the pooled strategy, all the YTs are shared among different QCs and thus any YT can deliver containers for any QC, which is a more flexible strategy for utilizing YTs. However, when YTs are shared by more than one QC (pooled dispatching) or a QC mixes the unloading and the loading operations alternately (dual cycle QC operation), both of which can be found rarely in practice, empty travels may be significantly reduced (Kim (2005) and Kim et al. (2008)).

The rest of the paper is organized as follows. In the next Section we present the literature review. The following Sections formulate several problems in relation to planning procedures at a container terminal and describes YT dynamic planning scenario. This is followed by the Sections which give system architecture and present a brief description of simulation modeling by pooling and yard monitoring screens with model structure, data collection and applied simulation algorithm. Computational results are reported to evaluate the efficiency of the models and improved results are presented in the following Section. Finally, we give some concluding remarks.

PREVIOUS RESEARCH STUDIES

Container terminal operations are often bottlenecked by slow YT movements. YT queues in front of the QCs and YCs are common. Hence, efficient YT scheduling to reduce the QC and YC waiting time is critical in increasing a container terminal throughput. Ship operations in practice are dynamic, therefore, demands online optimization. The objective of optimization in any case is to minimize the lateness of container deliveries for the QCs and the travel time of YTs.

The dynamic planning system for YTs problem falls in the category of the vehicle routing problems and more specifically, it has characteristics of backhaul due to the pickup and delivery processes involved in the problem. Numerous studies have been conducted regarding dynamic planning system for YTs problem presented at container terminals. Lee (2003) has made researches on improving the productivity of a container terminal by reducing initial investment costs and also by making the new system possible to be easily applied to the existing container terminal system. Seo (2004) has developed a design technique to build up a real-time marine observation system and then has introduced it. Also, by applying this system to Shinsundae Pier in Busan, he has tested the safety and efficiency of data recording and monitoring process. Kim (2002), in order to build up an efficient, integrated operation system of a container terminal, has suggested the structure and method for designing the crane management system of ATC (Automated Transfer Crane) and presented a newly developed pilot model. Liu et al. (2004) developed simulation models that were validated using real-life yard operational data obtained from the Norfolk International Terminal, USA. They showed that the yard layout has inevitable effects on the terminal performance and on the number of automated guided vehicles used. The results of their simulations indicated that the combined operation shows a great promise in increasing the terminal throughput and achieving high utilization of equipment in the yard. Nishimura et al. (2005) addressed the dynamic assignment rules of yard trucks to QCs and the associated optimization of trucks routing. At a dedicated container terminal, a set of YTs is in general assigned to a specific QC until the work is finished. They examined another type of assignment, which we named ‘‘dynamic assignment (or itinerary)’’, aiming to increase the productivity of the terminal. The problem can be defined by two formulations: one for trailer capacity of one container, the other for trailer capacity of more containers. Although the former is a particular case of the latter, it can be treated separately due to the easiness in its solution methodology. The genetic algorithm procedure that is employed for solving the problem for trailer capacity of more than one container is a heuristic and does not necessarily provide an optimal solution. Murty (2007) described the equipment used, and the operations inside the terminal only briefly to help the reader understand his strategy described of TOS (Terminal Operating Systems). The quality of service terminal operators can provide dependencies on their operating policies and the design of the terminal layout. He summarized some of these problems, and report on newer operating policies and designs which can help improve performance. Lee (2007), in order to solve the problem of information gap between the transfer equipment and the operation system in the container terminal and also for work control through real-time location information, has suggested a RTLS-based Dynamic Planning and realized a DPS (Dynamic Positioning System). Park et al. (2009) presented the results of the simulation models for dynamic resources assignment of YT based on real-time positioning. The YT performance for two alternative strategies has been evaluated, and system behavior observed. The results have revealed that simulation modeling is a very effective method to examine the impact of introducing improved strategy. Improved simulation model and pooled strategy of YT assignment would lead to an improvement of the main operational parameters. Koo et al. (2005) investigated design issue refers to the problem of fleet sizing and vehicle routing for containers to be moved by trucks between container terminals and off-the-dock CY. The approach suggested employing an optimization model to produce a lower bound on the required fleet size and a tabu search based heuristic to generate vehicle routing. Vis and Harika (2005) present a detailed comparison and sensitivity analysis of different types of automated transport vehicles (automated guided vehicles, AGVs and automated lifting vehicles, ALVs). Their simulation experiment shows effects on unloading times of a ship using different equipment. Yang et al. (2004) provided another simulation study of container terminal operations. By means of a simulation model it is demonstrated, that ALV is superior to the AGV in both productivity and economical efficiency principally because the ALV eliminates the waiting time in the buffer zone. Bish et al. (2007) analysed discharging and uploading containers to and from the ships. They address the dispatching of vehicles to containers so as to minimize the service time of a ship. Lehmann et al. (2007) considered situations occur that where different equipment units directly or indirectly request each other to start a specific process in automated container terminal. They developed different methods for the detection and resolution of deadlocks occurring in the resource-assignment phase. The suitability of these methods is demonstrated in an extensive simulation study.

The contribution of this paper to the existing literature is the following. First, we present the integration of QCs and YTs simulation planning problem that could provide an acceptable solution for the terminal links involved. Second, we develop a model to calculate the QCs and YTs performance. Third, we evaluate a more practical way of YT dynamic planning system, suggesting more diverse evaluation indicators and making it possible to check up the quality aspect of services at the container terminal by means of simulation. Fourth, we provide the performance analysis for both models. To this end, we have analyzed many benefits, when the RTLS-based YT pooling system is applied.

PLANNING PROCEDURES

The purpose of the study is to implement DPS (the dynamic planning system) for YTs based on RFID/USN (radio frequency identification/ubiquitous sensor networks) at container terminal. This study discusses how virtues of information technology enhancement activities are provided to raise port competitiveness. Advanced operation systems are actively being made, and determined from the viewpoint of investment effect. These systems are more preferable than infrastructure expansion and additional equipment acquisition. Using a simulation methodology, we have tried to prove that the real-time data collection by using RFID and dynamic operation of YT brings a positive effect on the productivity improvement and resource utilization enhancement. The development scopes are mother ship information management system, equipment management system, pooling management system, yard monitoring system, and reporting system. After this system has been designed and a new model has been made, its trial operation has been conducted in the actual container terminal. As a result of it, the following profits have been found out: (1) High Visibility of Container Terminal Resources Usage and (2) Container Terminal Productivity Improvement.

How to track and manage the location of containers, transfer equipment, stevedoring equipment, and workers is essential to enhance job efficiency and to strengthen safety and security. RTLS technology is very useful for this purpose. RTLS (Real-Time Location System) is a system that continuously tracks and manages the location of tangible assets and people on a real-time basis. It is composed of RTLS tag, RTLS reader, and RTLS LDT (Location Determination Technology) engine and application system (Lim (2003), Choi et al. (2005), Jeong et al. (2006), Shin (2008)).

The purpose of this study is to realize the dynamic planning system for yard tractors based on RFID/USN (Lim (2003), Hyndai (2007), Shin (2008)). The development scope of real-time monitoring application in the container terminal can be divided into three categories: The first is module for real-time data collection and filtering technology. So it includes the development of real-time data collection module for RTLS and the development of a data validity testing filter. The second is the development of a field work monitoring system. In order to test and apply dynamic operation, it includes the development of TOS simulator, real-time monitoring framework application, and RTLS-based YT pooling system.

We will use the concept discussed in which all YTs are considered as a pool serving the group of working QCs. We also adopt the YT dispatching policy developed there that helps minimize congestion. In the pooled strategy, all the YTs are shared among different QCs and thus any YT can deliver containers for any QC, which is a more flexible strategy for utilizing YTs.

TOS (Terminal Operating Systems) in container terminals plays a major role as it supports planning, scheduling, routing and YT control at a container terminal. In container terminals, the TOS is supposed to consider the real time operation of YT and then decides to assign jobs to different YT so that the performance is maximized.

In this study we give brief description of the dynamic planning system to find out the effect of layout on travel time of the trucks. Next, based on the data collected from the real situation, we decide on the optimal number of transfer cycle trucks implementing the dynamic planning system. This method is one of the methods of multi-criteria decision making that was explained in more details here. Finally, we prioritize the improved solutions using DPS.

In order to find out the current situation of the dynamic planning system for YTs, used in the Korean domestic industry, this study has classified its technology level into four categories: non-pooling, single cycle, pooling, and dual cycle. In case of domestic container terminals, most of them have not yet introduced a YT pooling system, and it has been found out that this system is much needed (Table 1). HBCT and PNCT are adopting a YT pooling system by each ship, but it is not based on RTLS. Because of this, its effect has been greatly reduced.

Table 1 – The current situation of the YT dynamic planning system

Type	Terminal name	Features	Remarks
Non-pooling	PECT BICT UTC, etc.	Inefficient yard operation	In pursuit of RTLS-based YT pooling and DC, but investment costs in communication network and VMT is not easy.
Single Cycle	PECT BICT UTC, etc.	Inefficient yard operation	In pursuit of YT pooling, but cannot afford to invest in communication network and VMT
Pooling	HBCT PNCT	YT pooling by each ship	Reduced effect because of absence of RTLS
Dual Cycle	N.A,	Failure experience because of lack of infrastructure (BCTOC)	Development of RTLS-based Y/T dynamic planning system is required.

Simulation of the logistics activities related to the arrival, loading/unloading, transfer and departure processes of YTs in container terminal can be carried out for different usages such as design of storage yard, increase productivity and efficiency of terminal equipments (YTs, QCs and YCs), analysis and planning of terminal transfer operations from the quay to the storage yard, etc. These logistics activities are particularly complex and very costly since they require the combined use of expensive infrastructure capacities especially berths and storage yard. Terminal transfer operations are required to serve containers as quickly as possible. Thus, in order to successfully design and develop terminal transfer operations and utilize it as efficiently as possible, it is necessary to develop a simulation model that will support decision making processes of terminal managers. The results, analysis and conclusions given here are intended to provide guidance on achieving time efficiency, raise productivity of YT and accuracy in the modeling and calibration of simulation models for considering terminal.

The YT assignment process is the allocation of handling tasks to container-handling equipment. Loading/unloading tasks are assigned to one of the QCs, based on the berth schedule and number of loading/unloading tasks for each ship. Transfer tasks are assigned to TCs dynamically, based on real-time information on waiting tasks and the status of each crane (Park et al. (2009)).

If the productivity of each area such as a quay, yard, and gate is harmoniously achieved, then the total productivity of a whole terminal can be improved. In particular, the productivity of YT in the container yard has a significant effect upon the overall productivity of a container terminal (Park et al. (2009)).

YT DYNAMIC PLANNING SCENARIO

In all, a visual means to use common sense as well as offer the possibility of simulation to solve operational, equipment and layout problems of Korean container terminals. The YT dynamic planning scenario design comprises of two modules. They were designed, programmed, tested, peer reviewed and validated as standalones.

Procedure of Container Handling

In order to realize the YT dynamic planning system, first of all, operation scenario has to be defined. The operation scenario begins just after a container comes through the gate and is stacked in the yard. However, when combined they form the complete dynamic planning scenario as shown in Figure 1.

All modules depicted in Figure 2 follow the YT dynamic planning chart at the time of unloading and by implementing the communications modules below outlines.

(1) Wireless LAN should be available between TOS and VMT of YT and YC or TC. Also real-time communication between TOS and RTLS system should be available.
(2) Information on the given mother ship should be downloaded, and equipment criteria information should be registered in the database.
(3) YT begins work as it downloads the unloading schedule from TOS. That is, YT travels to QC and loads the first container and then moves to TC.
(4) If the first container is unloaded from the TC, the TC driver touches the wireless terminal, simultaneously transmitting its result to the RTLS-based YT pooling system.
(5) Location information of YT and TC is to be received at an interval of 3 seconds, and also it is to be transmitted to RTLS-based YT pooling system.
(6) If the container is unloaded from the TC, RTLS-based YT job selection module is to receive the empty YT number and then produce an optimal YT job order, considering equipment criteria information, unloading schedule, and YT location information and transmit it to the VMT of the corresponding YT. At this time, the YT job order is to be realized in TOS.
(7) YT selects the optimum GC in order to transfer the container and loads it on the YT. At this time, an under-man confirms through wireless terminal that the container has been loaded on the specific YT.
(8) TOS orders YT to move to TC, indicating the block and bay in this case.

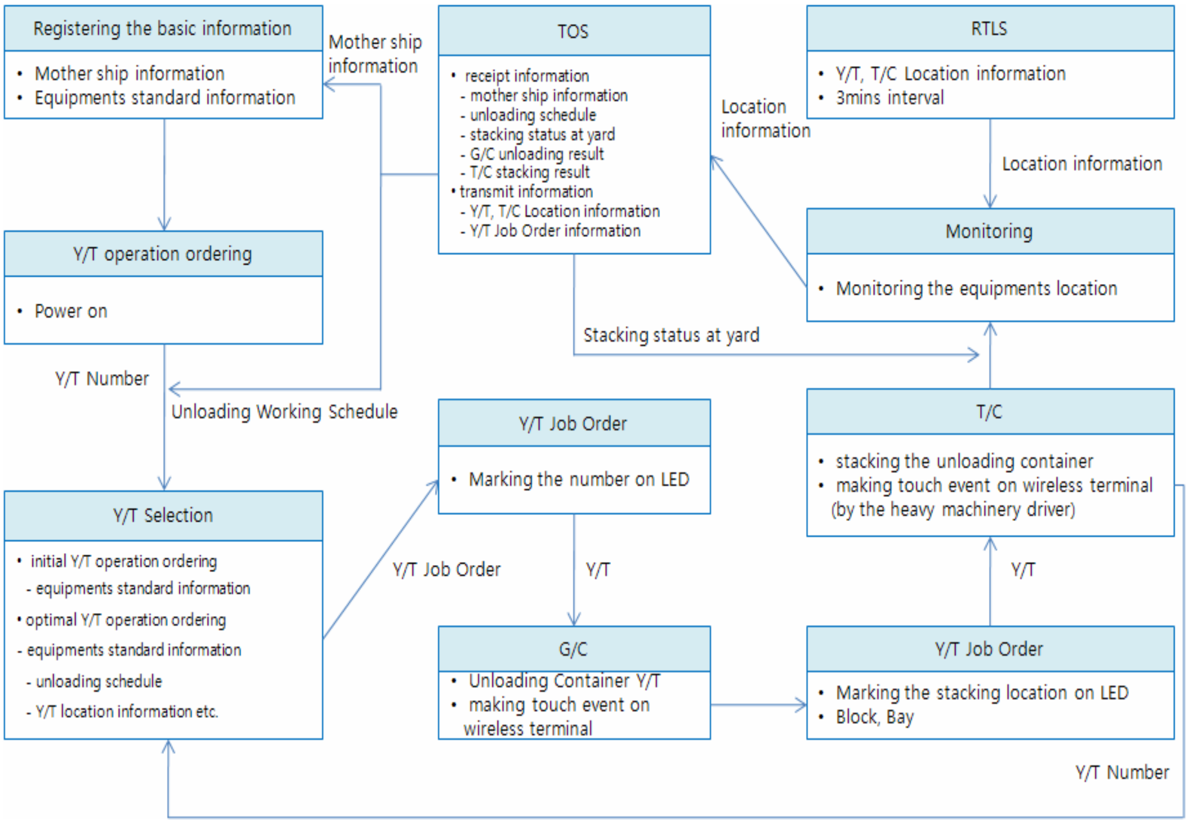

Figure 1 – YT dynamic planning chart at the time of unloading

Correlation Analysis between TOS and RTLS

This operation scenario allows the YT dynamic planning application to run on multiple computers whilst the database resides on the main server. Figure 2 shows correlation chart between TOS and RTLS.

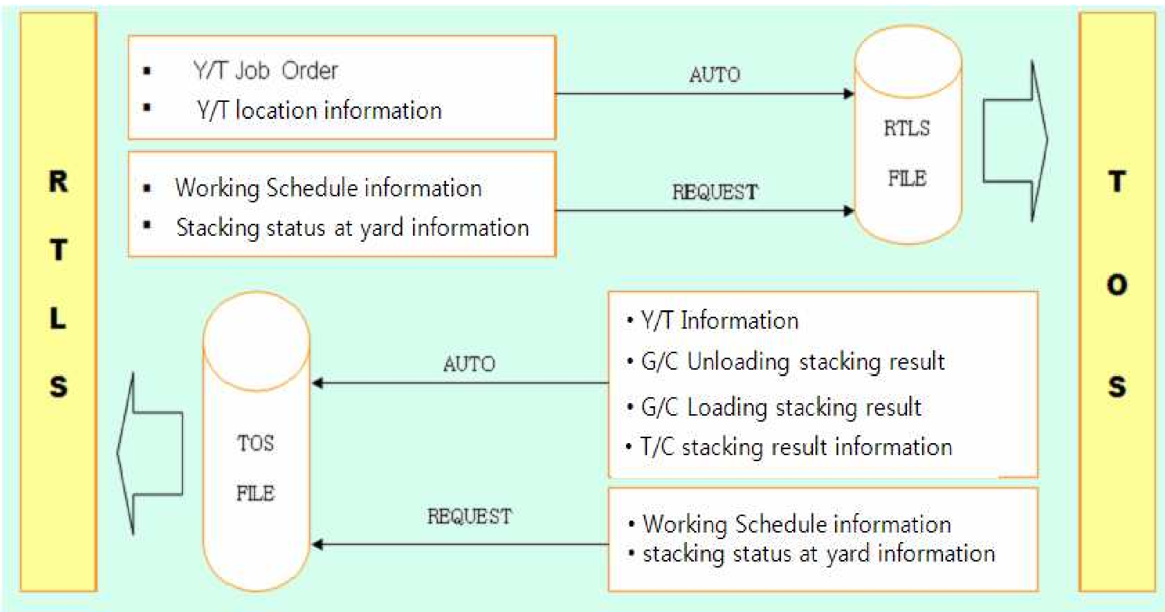

Figure 2 – Correlation chart between TOS and RTLS

TOS, the operation system of a container terminal, is holding all kinds of job history and necessary information including container gate-in/gate-out, container stacking, transfer, loading and unloading. RTLS is a system for YT dynamic planning, while playing the role of front end. Therefore, the relationship between TOS and RTLS has to be defined, see Figure 2. RTLS automatically provides YT job order and location to the TOS, and if necessary, it can ask for information on job schedule and yard storage. TOS automatically transmits the following information to the RTLS: Y/T information, information on QC loading and unloading, information on TC loading and unloading, and information on the results of yard stacking.

SYSTEM ARCHITECTURE

The major modules of RTLS-based YT pooling system are as follows:

- mother ship information management system,
- equipment management system,
- information request system,
- a system for setting up yard resources,
- pooling management system,
- Y/T pooling situation management subsystem and
- yard monitoring system.

The subsystems composition is as follows.

Mother Ship Information Management Subsystem
Visiting ships have a variety of their ship resources. The berthing length and the necessary number of Y/Ts usually depend on the ship's size. The essential information items include: ship code, ship name, ship photo, call sign, the maximum number of bays and the maximum number of decks, ship length and width.

Equipment Management Subsystem
All the equipment used in the container terminal is to be registered in the subsystem. The essential information on all the equipment includes: equipment number, equipment type, equipment name, *tag:* Mac address, equipment productivity (move/hour), equipment speed (km/hour), GC boom-up hour, and equipment image. The equipment includes two kinds: yard truck and yard crane. And these two equipments are equipped with RTLS tag along with its code and *tag:* Mac address.

TOS Information Request Subsystem
The RTLS system is to receive information from TOS. The essential information that RTLS system requests includes mother ship arrival and departure information, container shipment information, and loading and unloading schedule. The mother ship arrival and departure information includes the following: year, mother ship code, navigation number, mother ship name, total length, arrival date, arrival hour, departure date, departure hour, the number of containers to be discharged and to be loaded, and the next visiting port. Figure 3 represents information delivery process of TOS and RTLS.

Loading and discharging schedule information includes the following: year, mother ship code, navigation number, identification of loading and discharging (discharging - D, loading - L), QC (G/C), working sequence number, container number, size, type, F/E (Full - F, Empty - E), location within the ship (block, bay, row, tier), and yard storage location.

TOS information transmission module consists of a send-and-receive data handling module and a send-and-receive Daemon. The send-and-receive data handling module queries the related data from TOS, converts it in the form of file, copies into the appointed place of the

TOS server, and calls the send-and-receive Daemon. The send-and-receive Daemon (TOS) module confirms communication situation with RTLS and transmits the file in the appointed place of TOS to the RTLS.

Subsystem for Setting up Yard and Block Resources

In order to check the movement of YT and TC inside the container terminal and to give an optimum job order, the yard and block resources of the container terminal should basically be displayed on the computer screen. The management items that indicate the yard are composed of beginning coordinate (X, Y) and ending coordinate (X, Y). The blocks in the container yard include the number of blocks, length, width, the height of block, beginning coordinate (X, Y) and ending coordinate (X, Y).

YT Pooling Definition Subsystem

Before introducing a YT pooling system, YTs have to be allocated according to each QC. Because of this, shortage of YTs has happened or waiting time has occurred. However, YT pooling system has brought the efficient usage of YT. The YT pooling subsystem by mother ship selects a mother ship and allocates QC and YT for a pool. Pooling distinction can be made by pooling number, and mother ship distinction can be made by arrival year, mother ship code, and navigation number.

Registration of QC and YT can be done by way of selecting equipment code by mother ship. The equipment allocated to a pool is to be shown as “in use” and the equipment not allocated to a pool as “not in use.” In particular, in case of registering plural mother ships, the mother ship incapable of pooling has to be selected.

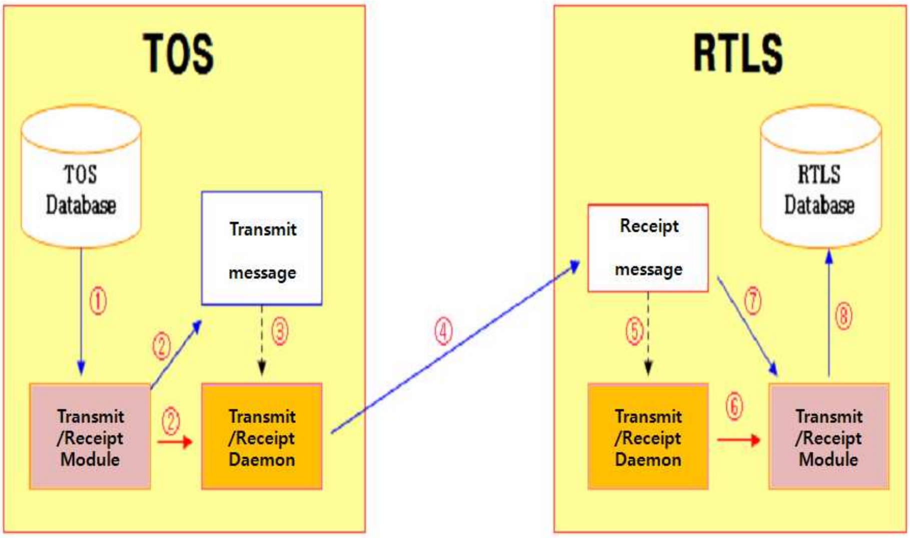

Figure 3 – Information delivery process of TOS and RTLS

YT Pooling Situation Management Subsystem

If YT pooling is completed, it will be shown on the pooling monitoring screen at fixed cycle intervals. In case of automatic indication, it will be set at a cycle time of 5 seconds to the minimum and 60 seconds to the maximum. In particular, this subsystem includes the module that gives an optimum job order to the YT for the sake of YT dynamic planning. Figure 4 presents pooling monitoring screen.

Yard Monitoring Subsystem

If a RTLS-based YT pooling system is put into operation, this subsystem shows the location of all the equipment on a real-time basis. Also it includes the following information such as mother ship information, equipment information, yard/block information, and yard storage information. If a mouse moves over the menu items such as equipment, block, building, and vessel, it will show the names of further detailed menu items, because it has a tool-tip function. Figure 5 shows yard monitoring screen.

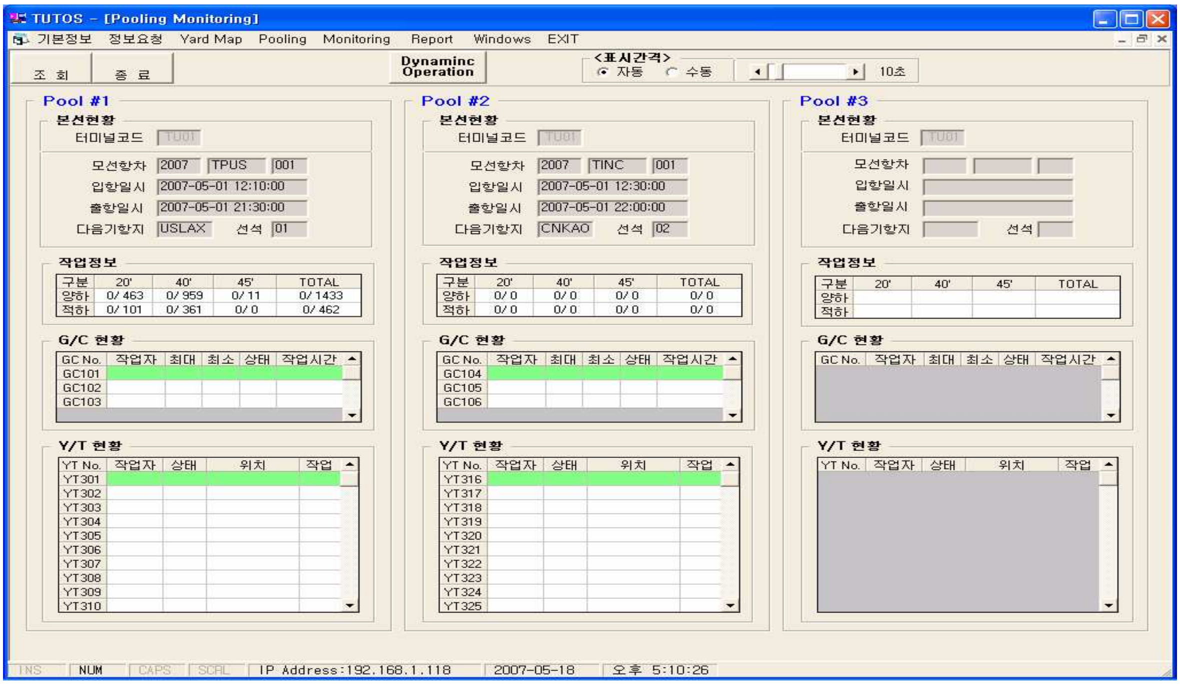

Figure 4 – Pooling monitoring screen

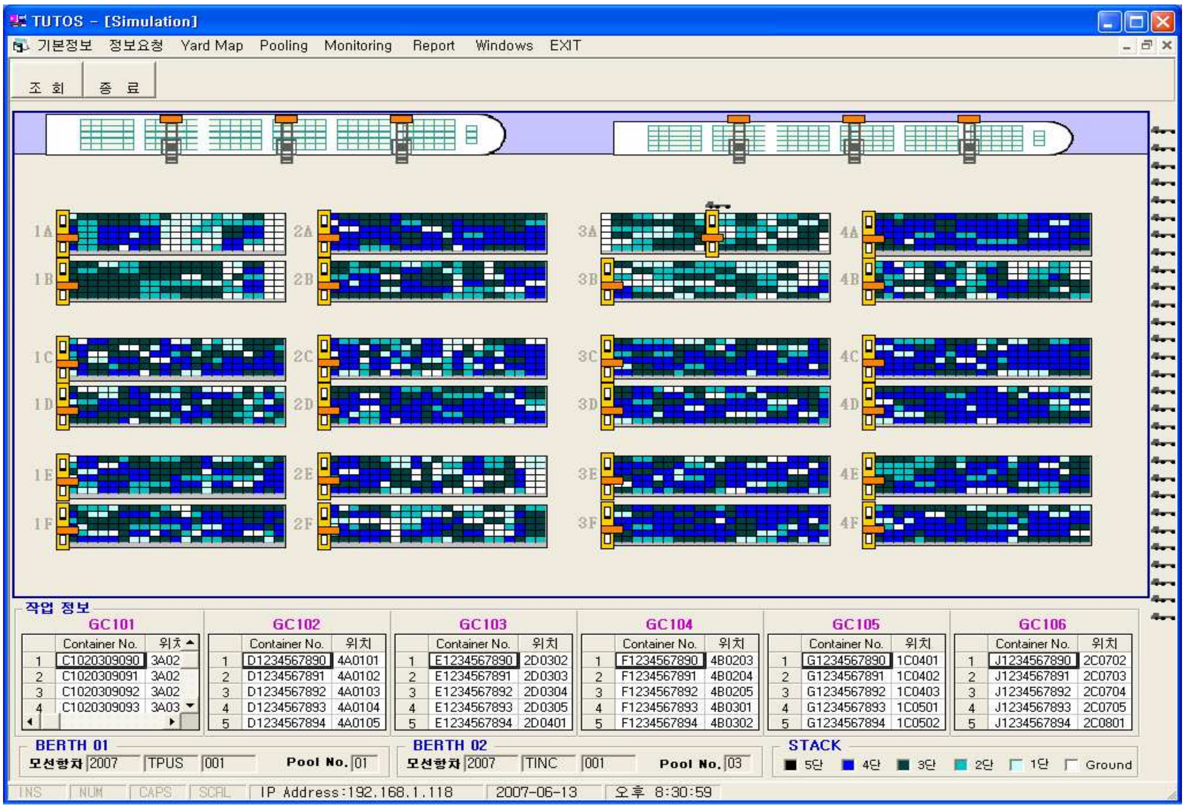

Figure 5 – Yard monitoring screen

SIMULATION MODELING

In this Section, we first discuss the YT deployment system. To attain the highest terminal productivity, it is vitally important that the activities of the YTs must be properly coordinated so the YTs serve QCs effectively. The above mentioned highlights the challenging nature of real-time YT operations control problems at a container terminal. Accordingly, we have considered two types of strategies for assigning delivery tasks to YTs: dedicated strategy and a pooled strategy. Then simulation models for both of them have been performed to measure their quantitative effect. The two YT assignment strategies presented here are directly tied into a detailed simulation models: current model for dedicated strategy and improved model related to pooled strategy. Both models are tested and shown to be viable in a real-time environment. Computational results indicate that one of these models is superior to the other.

In order to improve the reliability of each simulation model, we have collected the operation data of Hanjin Gamman Container Terminal (HGCT) located in Busan for one year (Park et al. (2009)). We have used Arena as a simulation language (Kelton et al. (2003)) and a Visual BASIC for a linkage to event handling. According to the realized interview, we address problem at HGCT, where YTs are assigned to specific QC until the work is completed. A more efficient YT assignment method called pooled strategy will be proposed. In this process, YTs return to any QC after delivering the containers and YTs can be dynamically assigned to the QC. Dynamic approach may be more advantageous, such as: when a YT arrives at a container stack point in the yard after receiving a container from a QC under unloading operation, instead of going back to the QC which is situated far from the present location, it proceeds to the next stack point which is close to the present location, to receive a container for export, and then proceeds to another QC under loading operation.

Terminal transfer operations are required to serve containers as quickly as possible. Thus, in order to successfully design and develop terminal transfer operations and utilize it as efficiently as possible, it is necessary to develop a simulation model that will support decision making processes of terminal managers. The results, analysis and conclusions given here are intended to provide guidance on achieving time efficiency, raise productivity of YT and accuracy in the modeling and calibration of simulation models for HGCT.

Simulation model development is required to test the efficacy of dynamic operation based on RTLS. We need to analyze the current business process and then to design an improved business process. A current model YTs operation method is based on group of YTs, that is, a certain number of YTs per QCs, thus performing the job of loading and unloading for QC. At this time each YT group can be distinguished by their flag. Fig. 6 shows current YT operation concept of the dedicated strategy where a group of YTs is assigned to a QC and deliver containers only for that QC.

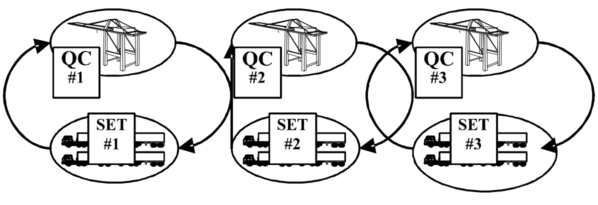

Figure 6 – An illustration of current YT operation concept (dedicated strategy)

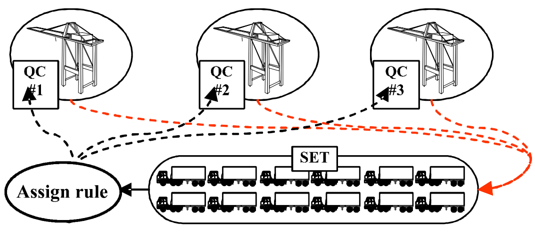

Figure 7 – An illustration of improved YT operation concept (pooled strategy)

Considering the dedicated strategy, YTs can be assigned per QCs orderly, which offers positive results. On the other side, it makes it impossible to exchange mutual cooperation with YTs belonging to the other groups. Consequently, job flexibility lowering and the availability of equipment are also expressed here. In additional, YT's loaded travel and an empty travel are alternately repeated (called single cycle operation) between a QC and YCs. It happens because YTs are usually assigned to a single QC (dedicated assignment) and QCs start the loading operations only after all the unloading operations are completed.

Different from the above-mentioned is pooled dispatching strategy. In the pooled strategy, all the YTs are shared among different QCs and thus any YT can deliver containers for any QC as illustrated in Fig. 7. This strategy can be composed for a ship or for a whole container terminal.

As this method is FIFO-based assignment of YT, it can coordinate the YT imbalances utility rate. Referring to the job situation including the moving distance from the current job place, YTs can be dynamically assigned to the QC and YC, thus considerably reducing empty movement.

Initial Environment Simulation Setup

This study has assumed that one berth has three QCs, one QC has one group organization composed of five YTs, and each group works for 10 hours. Transfer distance has been counted according to the required time of each movement lines for YTs as illustrated in Fig. 8 (environment setup for a current model). On the other side, the improved model based on 15 YTs has been dynamically assigned to 3 QCs. The environment setup provides another powerful advantage for improving the YT assignment processes at the HGCT.

An important part of the models implementation is the correct choice of the values of the simulation parameters. The input data of the mother ships are collected for one year (2005) (Park et al. (2009)). Related to statistical analysis obtained data come from the HGCT and includes the following values: arrival and departure time of mother ship, work time, number of assigned QCs, number of YTs, number of YCs, and storage position at the container yard. The average of each values and probability distributions were calculated by input analysis with Arena. YT's waiting time for YC, working hours, YT's travel speed and transfer distance have been calculated based on real data. Table 2 and Figs. 8 and 9 show the values of major input variables.

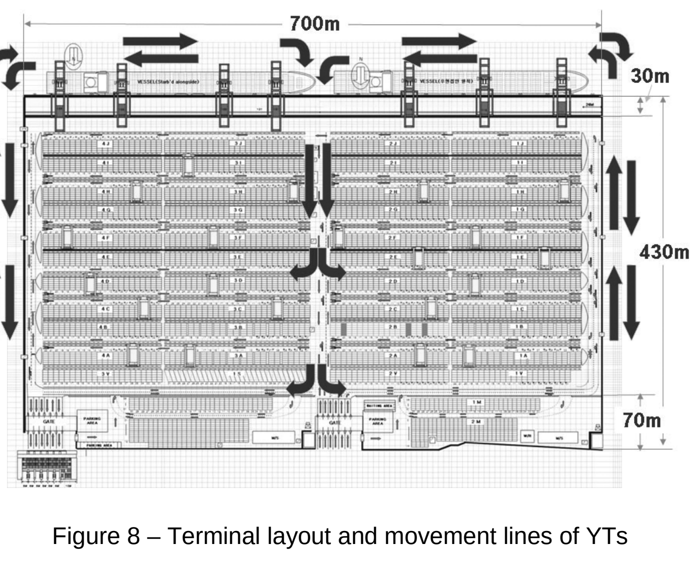

Figure 8 – Terminal layout and movement lines of YTs

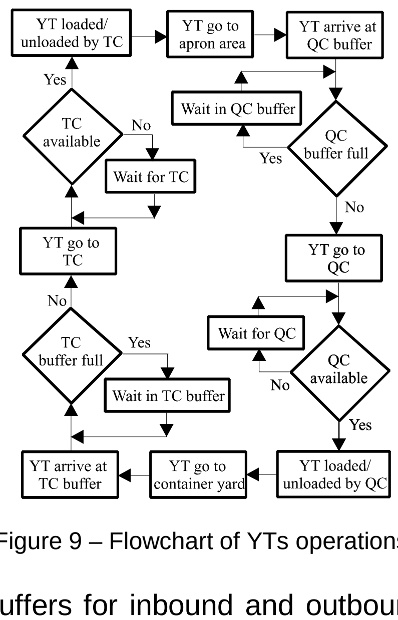

Figure 9 – Flowchart of YTs operations

Storage yards at container terminals serve as temporary buffers for inbound and outbound containers. YTs are the most frequently used equipment at terminal for transfer operations. The efficiency of transfer operations heavily depends on the productivity of these YTs. As the workload distribution in the terminal changes over time, dynamic deployment of YTs between quay and container storage areas is an important issue of terminal operations management. These models address the YT deployment problem. Given the forecasted workload of each YT in each period of a day, the objective is to find the assignment strategy and routes of YT movements between quay and storage yard so that the productivity at terminal is improved and average delay time of QC is minimized. The problem is solved by simulation model. To improve the performance of this approach, we augment the new model and modify the solution procedure accordingly. Computational calculation shows that the modified model generates better results.

Table 2 – The major simulation input variables

Variable	Type	Value
Service time distribution of ships	Distribution	1+GAMM (2.58,5.48) hrs
Number of QC	Average value	3
Loading time for QC	Distribution	TRIA (20,30,40) sec
Number of YT	Average value	5 YTs per QC
Travel speed of YT	Average value	115 meters/minute
Waiting time distribution of YC	Distribution	TRIA (0.4,1,1.5) minute
YC working hours	Distribution	NORM (3,0.2) minute
YT's transfer distance	Considering the port layout and movement lines which are converted into meters.	

In particular, simulation modeling is suitable for the complex environment of a container terminal, which requires various criteria and scenarios. Most container terminal systems are sufficiently complex to warrant simulation analysis to determine systems performance.

We now present simulation models of dynamic transfer operations based on RTLS. These models, based on the authors experience and on extended discussions with managers and staff members at HGCT, are designed to show dependence of assigning strategies for YTs in real time.

Let's assume that we conduct modeling based on one ship. The modeling can be divided into three parts. Firstly, if containers come, it needs to be checked whether there are YTs available or not. If available, YTs will be assigned to QC, and if not, QC is to wait YTs. In the same time, the QC's waiting time for YT is counted. This procedure is explained in Fig. 10. Group of 5 YTs has been assigned by using the transporter module for QC referring to Table 3 (Park et al. (2009)).

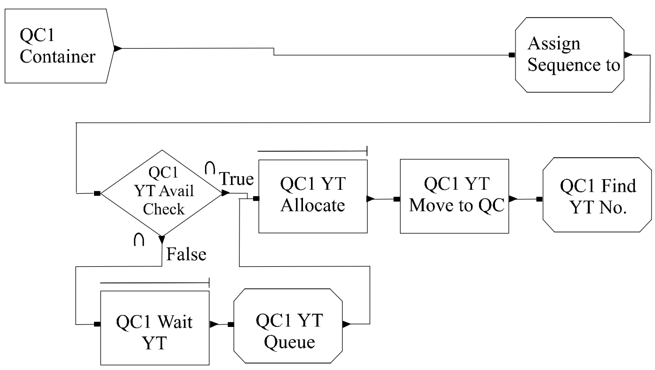

Figure 10 – Sub-model for YT available after job completion of QC

Secondly, if YTs are assigned, the corresponding containers will be loaded on the YTs, and move to the YCs. In the same time, the YT moving distance becomes the movement lines to the destination. If YC is under work, YT has to wait related to Fig. 11. At this point, the moving distance of YT is measured by a distance module displayed in Table 4 (Park et al. (2009)).

Table 3 – Transporter module

	Name	No. of YTs	Type	Distance Set	Travel speed (m/s)	Initial Position
1	QC1 YT	5	Free Path	QC1 YT Distance	10	QC1 Station
2	QC2 YT	5	Free Path	QC2 YT Distance	10	QC2 Station
3	QC3 YT	5	Free Path	QC3 YT Distance	10	QC3 Station

Table 4 – Distance module

	Distance Module Name	Beginning Station	Ending Station	Distance (Meters)
1	QC1 Yard Truck Distance	QC1 Station	YC1 Station	378
2		YC1 Station	QC1 Exit	621
3	QC2 Yard Truck Distance	QC2 Station	YC2 Station	351
4		YC2 Station	QC2 Exit	486
5	QC3 Yard Truck Distance	QC3 Station	YC3 Station	621
6		YC3 Station	QC3 Exit	297

Finally, if YC's storage work is over, YTs will be released, and containers handling will also be ended. This procedure is shown in Fig. 12 (Park et al. (2009)).

One of the productivity terms is the time of YTs for one container, which is incurred by the travel of trucks in the yard. The travel time is proportional to the travel distance of YTs and availability of YC at time. YTs travel from the quay to the storage yard and then return to the quay. The model developed here can be used to obtain results that can be important to the terminal management.

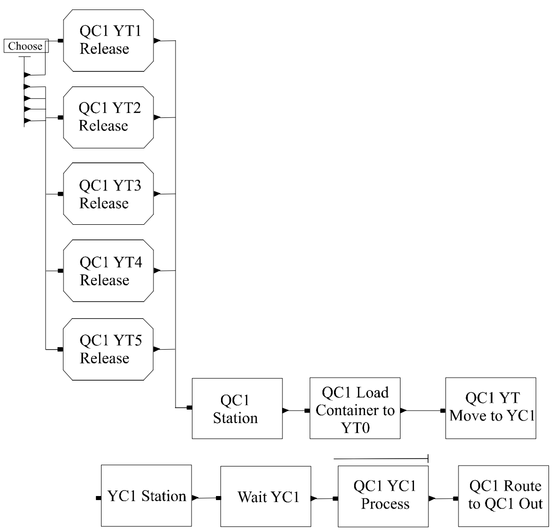

Figure 11 – Sub-model for YT moves to QC

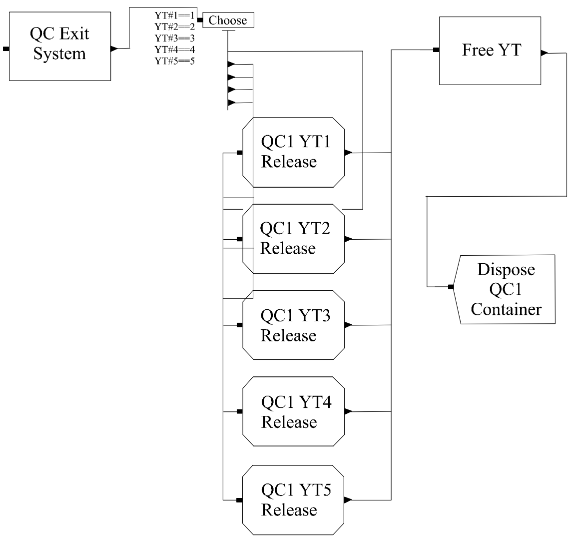

Figure 12 – Sub-model for YC's storage work is over, YT is released

If the above-mentioned modules are connected, the modeling for one berth is completed. And this modeling is used for the three berth container terminal programming. A new improved model is similar to the current model, but the difference is that YT is not assigned to a specific QC. Besides, if YTs are free, they are to be assigned to the nearest QC. Fig. 13 illustrates the difference between the two models (Park et al. (2009)).

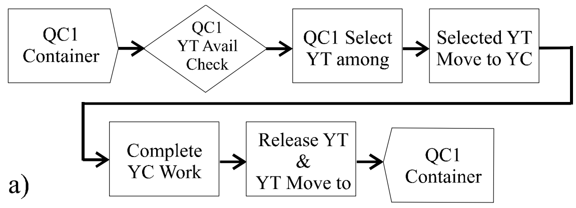

Figure 13 – Difference between the current model (a) and the improved model (b)

RESULTS

In this section, we compare the performance of both motels. The Arena software has been used for solution procedure. We simulate the models with their data and initial environment setup for simulation as described in previous Sections. To obtain a high accuracy, sufficient replication should be simulated. The simulation models were run for 100 statistically independent replications. The average results were recorded and used in comparisons. Two different models were simulated referring to Fig. 13. The two models had 5 and 15 YTs, and their delivery orders, respectively. Group of 5 YTs has been assigned to QC for current model. The improved model based on 15 YTs has been dynamically assigned to 3 QCs according to resource conditions and shortest distances.

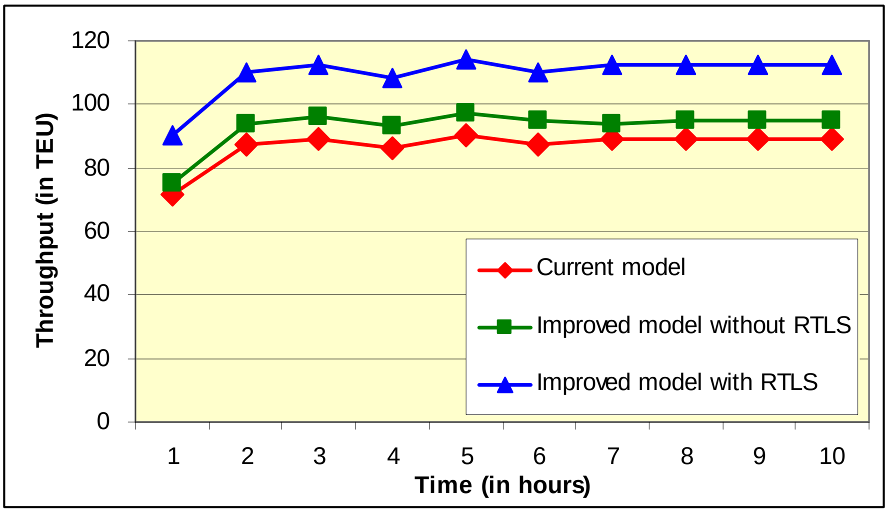

Figure 14 – The status of throughput according to time progress

Figs. 14 and 15 show the experimental results for major output values for the current and improved model. These results presented support the argument that the total handling volume and handling volume per YT could be increased by pooled strategy of YTs. At the same time, the objective is to minimize the average delay time of QC in YT waiting time, and hence the average time that YTs spend in quay area. Our results show that YTs arrivals over time are needed as input data for the optimization of the considered problem. In addition to the arrival date and YTs time in quay area, it also generates the number of lifts per ship (i.e. the number of containers to be served per ship). On the basis on YT and QC productivity, this number of lifts per ship can easily be converted into the average service time of YT needed at the quay area.

Fig. 14 shows the status of throughput according to time progress, while Fig. 15 gives the relationship between delay time and throughput. Figure 14 compares the status of throughput according to time progress of different models at a terminal. They graphically show the sensitivity of throughput. Figure 15 presents how delay time of YTs reduces the throughput for each model. The obtained results shown here support the argument that the throughput could be decreased by increasing delay time of YTs.

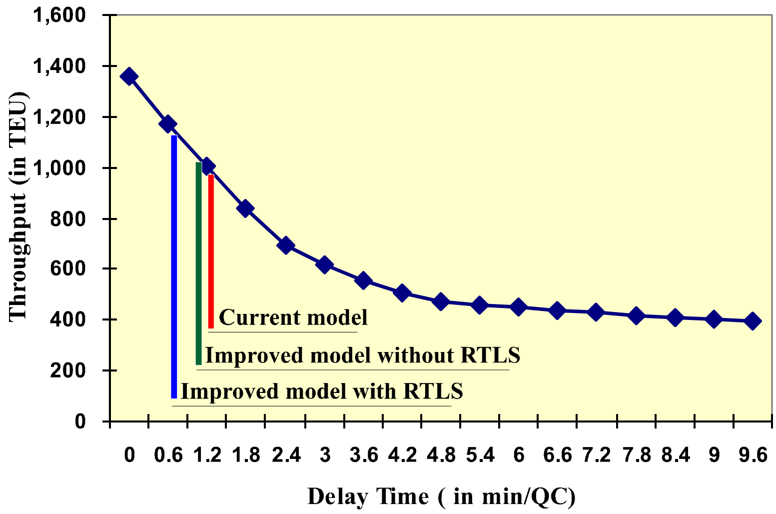

Figure 15 – The relationship between delay time and throughput

In order to enhance the readability of simulation, animation has been made. Also, for easy understanding of YT's flow, the animation has been expressed as shown in the Fig. 16.

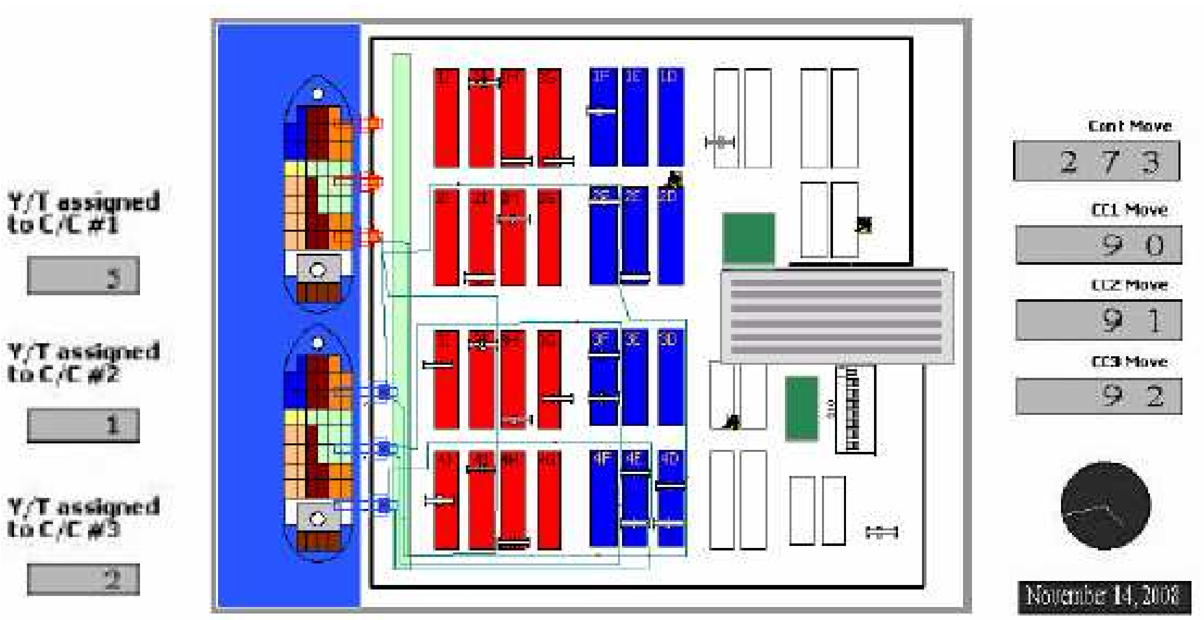

Figure 16 – Simulation animation

CONCLUSIONS

The results of both simulation models include total handling volume, handling volume per YT, average delay time of QC in YT waiting time and the relationship between delay time and throughput. The strategy assignment, based on real-time positioning, is introduced next in order to improve the performance parameters of the terminal transfer operations. Priority is therefore assigned pooled strategy of YTs to each YT and the output is considered in order to help port management establish the best service strategy. To achieve accuracy, we first evaluate the queue properties, and then we deal with productivity of YTs.

In this paper we have presented a new approach that combines the advantages of simulation models and the dynamic transfer operations based on real-time positioning. We have shown that our improved model is able to generate competitive solutions quickly, even compared with traditional planning approaches that are much more time consuming.

RTLS-based YT pooling system is making a great contribution to improving the productivity of a container terminal. Domestically, YT pooling system is at the entering level, but RTLS technology has not been introduced. For this reason, this study has tried to develop a RTLS-based YT pooling system, creating its trial product, and applying it to the field for experiment.

The results of this study show that the RTLS-based YT pooling system is composed of the following system modules: mother ship information management system, equipment management system, information request system, system for setting up yard resources, pooling management system, yard monitoring system, and reporting system. This study has also found that the new system has brought an efficient usage of various equipments in the yard, reducing fuel cost, and consequently saving stevedoring costs.

RTLS can be applied to yard automation system. RTLS technology can reduce both works delay and mistakes that can be caused by human judgment, consequently enhancing the productivity of the yard. In addition, RTLS makes it possible to track the position of workers and monitor on a real-time basis, so that it can contribute to improve the job efficiency of workers, strengthening the security in the restricted area, and reinforcing safety by keeping workers from approaching dangerous area.

In spite of the above-mentioned many benefits, when the RTLS-based YT pooling system is applied to the field, the location precision is still supposed to be low more or less. Therefore, the time has not yet come for it to be applied to the whole of yard work. For successful application of a RTLS-based system, the location precision of a RTLS tag has to be improved. Meanwhile, since the position of workers is tracked on a real-time basis, the problem of personal information protection can be raised.

As a result of our research, it has been found out that the dynamic resources assignment of YT based on real-time locating data can raise productivity by more than 25% over the dedicated assignment method. If an error range is reduced by using RFID technology, and also if RTLS is applied not only to the YT, but also to the YCs and containers, than higher productivity improvement is expected.

Recently, port operation systems of many advanced countries are becoming more intelligent and object-oriented, and also tremendous efforts are being made to actively and speedily respond to the rapidly changing environments. To the end, RTLS technology is coming to the fore. In this respect, this study is expected to make a contribution to the introduction of RTLS.

Further research on the issue of the RTLS-based YT pooling system could proceed in several directions. For example, additional simulation experiments which consider other container terminals and various improved scenarios could be performed.

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