Dynamic Resources Assignment based on Real-Time Positioning in Container Terminal

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Abstract: - By virtue of information technology enhancement, many efforts to raise port competitiveness through an advanced operation system are actively being made, and judging from the viewpoint of investment effect, these efforts are more preferable than infrastructure expansion and additional equipment acquisition. Based on simulation, this study has tried to prove that RFID-based real-time location data collection and dynamic operation of transfer equipment brings a positive effect on the productivity improvement and resource utilization enhancement. Also, our researches on the demand for the real-time data for port operation have been made, and operation processes have been redesigned along with the collection of related data, and based on them, simulations have been conducted. As a result of them, about 25% of productivity improvement has been realized.

Key-Words: - Dynamic Operation, Dynamic Planning, Simulation, RTLS, Yard Tractor Pooling

1. Introduction

1.1 Necessity of Research

In order to enhance port competitiveness, fierce efforts for operation efficiency are being made. These efforts for operation efficiency covers the following directions: infrastructure establishment through berth expansion, labor saving through the capacity improvement of stevedoring equipment and increase of equipment unit, and information intensification and automation for an operation system.[5]

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 horizontal transfer equipment in the container yard has a significant effect upon the overall productivity of a container terminal.

Productivity maximization of transfer equipment, minimization of C/C and T/C waiting time by effective fulfillment of work order, and remarkable utility rate improvement by dynamic vehicle assignment – all these are essential technologies for state-of-the-art port stevedoring system.[9] For this reason, in order to increase the efficiency of transfer equipment, the development of a dynamic assignment technique (or dynamic operation) based on a real-time location system is badly needed.

This study has grouped the assignment problem of transfer equipment into two: an existing batch and sequential method and a dynamic assignment method. And then simulations for both of them have been performed to measure their quantitative effect.

Also, this study has divided a simulation model into a current one (As-Is) and a future (To-Be) model. In order to improve the reliability of each simulation model, we have collected the operation data of “P” container terminal located in Busan for a full year. We have used Arena as a simulation language, and have used a visual basic for a linkage to event handling and excel file.

Based on the previous studies and the interviews with specialists, current situation has been analyzed, and the process logic has been made on the basis of these researches. Programming has been performed after data collection and data analysis, and the results have been analyzed through the tests.

The definitions of terms in this study are as follows.
RTLS: RFID based real-time locating system. [3]
YT pooling: joint assignment of yard tractors
Dynamic operation: optimal assignment of yard tractors based on real-time data

2. Basic Research

2.1 Literature Review

Concerning an effective remodeling of a container terminal, Choi Yong-Seok[9] et al. have suggested a model by area, that is to say, a gate, a quay, and a yard, and priority order has been set according to a questionnaire and a simulation. According to his research, the effective remodeling for a quay and a yard is Y/T pooling operation [1] and dual cycle operation.[2]

Kim Jin-Tae[4] has conducted a simulation by using a Markov Decision Process model to improve an efficiency of vehicle shipment by railroad. As a result, he has proved that an RFID based dynamic decision-making method is much better than a conventional decision-making method from the aspect of both utility rate and customer satisfaction.

We can find in many literatures that simulations have been widely used in order to improve port productivity. For example, the Total Soft Bank of Korea has developed a port simulation,[7] which is now being used for port planning. In 1969, the classic of port simulation, UNCTAD port model has been created[8]. In early 1980s, MIT Port Simulation[8] has been made in order to analyze the operation efficiency of a multi-purpose port. There is PORTSIM, which has succeeded in enhancing the efficiency of a simulation through animation and visualization. Also, there are a GMTS of JWD, QuickTerm of M&N, POSPORT of Posford Duvivier, and CTS of ECT[5]. In 2005, OptiPort computed the optimal throughput for various Container Terminal types [8].

All these port simulations are mainly aiming to forecast logistics volume, and to seek an optimal infrastructure and proper equipment combinations, so that they have been used at the planning stage of port construction. Recently, leading port operators such as HIT and DPW are developing a new simulator in order to advance an existing port operation system.

2.2 Operation Situation of Container Terminal and Its Requirements

In an effort to make a survey of utilization of real-time data, to find out current operational problems, and to listen to the field experts' requirements for improvement, we have visited major container terminals five times from October to December 2006. As the interviewees were composed of managers who have experiences of more than 10 years, they can tell us about the necessity of real-time data and also provide us with the necessary data for simulations. By fact-finding field survey, we have found out the following operational problems and the requirement for advancement.

2.2.1 Operational Problems

In most cases, the bottlenecks in the operational process are usually caused by transfer equipment rather than quay cranes or yard cranes.

In the case of one or two ports, a pooling system or a dual cycle system has been adopted for the load balance of transfer equipment. But because of inaccurate location recognition and scanty wireless communication infrastructure, they have ended up in failure.

In case of most domestic ports, the final job location of a crane can be checked by crane operator's input, consequently lowering the accuracy of input data, and in case of transfer equipment, it is almost impossible to conduct location tracking.

2.2.2 Requirements for Improvement

According to interview, equipment on transfer crane for a job completion notice and an automatic sensor for jobs to be done on yard tractor are needed. Tracking of yard tractors is conducive to the enhancement of operational efficiency from the aspect of situational assignment of transfer equipment.

In order to show the evidence for effectiveness of dynamic planning, it is necessary to handle more than three berths in making simulation model rather than a small-scale container terminal.

3. Process Analysis and Redesign

3.1 As-Is Analysis

In the development of a simulation model to test the efficacy of dynamic operation based on RTLS, first of all, we need to analyze the As-Is business process and also need to design a To-Be business process. A As-Is Y/T (yard tractor) operation method is based on a team unit, that is, a certain number of Y/Ts per C/C (container crane), thus performing the job of loading and unloading for C/C. At this time each Y/T team can be distinguished by its flag . (Fig. 1)

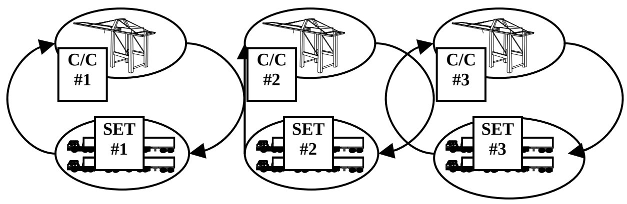

Fig. 1 As-Is Y/T Operation Concept

In the sense that this batch and sequential operation of Y/T for shipment on board the ship can be done orderly, it has a positive meaning, but it makes it impossible to exchange mutual cooperation with Y/Ts belonging to the other teams, consequently lowering job flexibility and availability of equipment.

3.2 To-Be Model

Different from the above-mentioned batch and sequential operation of Y/T, a dynamic operation system doesn't have a job team composed of transfer equipment. Instead, Y/Ts freely support the job of several C/Cs. That is to say, Y/T pool can be composed for a ship or for a whole container terminal Fig. 2.

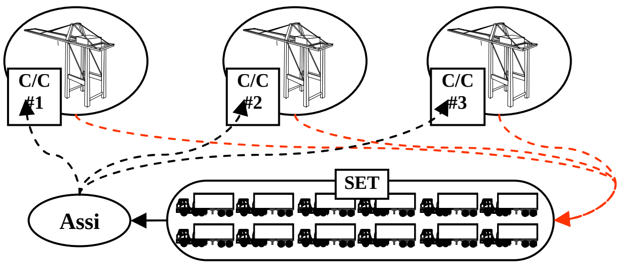

Fig. 2 To-Be Y/T operation concept

As this method is FIFO-based assignment of transfer equipment, it can coordinate the imbalanced utility rate of transfer equipment. Also, considering the job situation including the moving distance from the current job place, Y/Ts can be dynamically assigned to the C/C and T/C, thus reducing empty movement considerably.

4. Simulation Input/Output Variables Setup

4.1 Initial Environment Setup for Simulation

With regard to environment setup related to job situation, in case of a As-Is model, this study has assumed that one berth has three units of C/C, one C/C has one team organization composed of five Y/Ts, and each team works for 10 hours. Running distance has been counted according to the required time of each movement line of Y/Ts (Fig. 3). In case of the To-Be model, most conditions are similar to the As-Is model, but the only difference is that 15 units of Y/Ts have dynamically been assigned to the three units of C/C.

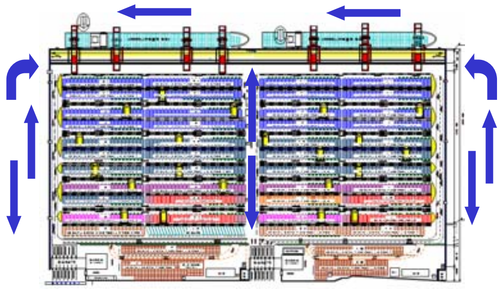
Fig. 3 Movement line of Y/Ts

4.2 Input Variables

In order to produce an input data, we have collected the data of the mother vessel for one year of 2005 at the "P" container terminal. The data includes: arrival and departure time per mother vessel, work time, number of assigned Q/C, number of Y/T, number of T/C, and storage position of the containers required to be carried. All the average values and probability distribution values have been calculated by input analysis of Arena. Y/T's waiting time for T/C, working hours, Y/T's running speed and distance have been calculated according to the judgment of field experts. Table 1 and Fig. 4 show the values of major input variables.

Table 1 Major simulation input variables

Variable	Type	Value
Service time for ships (from arrival to departure)	Distribution	1+GAMM (2.58,5.48) hrs
Number of C/C	Average value	3 units
Loading time for C/C	Distribution	TRIA (20,30,40) sec
Number of Y/T	Average value	5 units/1GC
Running speed of Y/T	Average value	115 meters/min.
Waiting time for T/C	Distribution	TRIA (0.4,1,1.5) min.
T/C working hours	Distribution	NORM (3,0.2) min.
Y/T's running distance	Considering the port layout and movement lines, they are converted into meters.	

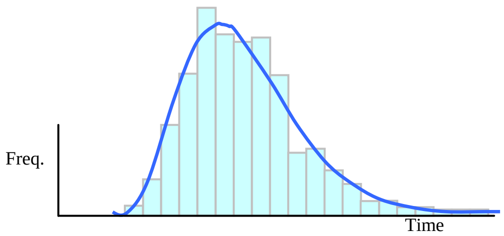

Fig. 4 Distribution of Service Time for Ship (1+GAMM (2.58,5.48) hrs)

4.3 Output Variables

Input variables are: total handling volume at the same hours, handling volume per Y/T, and delayed working hours owing to Y/T's waiting. And then the research on corelationship between handling volume and Y/T's working hour delay has been made.

5. Simulation Modeling

5.1 Modeling

Let's assume that we conduct modeling based on one ship. The modeling can be divided into three parts. First, if containers come, it needs to be checked whether there are available Y/T or not. If available, Y/Ts will be assigned to C/C, and if not, C/C is to wait Y/Ts. At this time, the C/C's waiting time for Y/T is counted (Fig. 5). 5 Y/Ts per team have been assigned by using the transporter module for C/C of three units (Table 2).

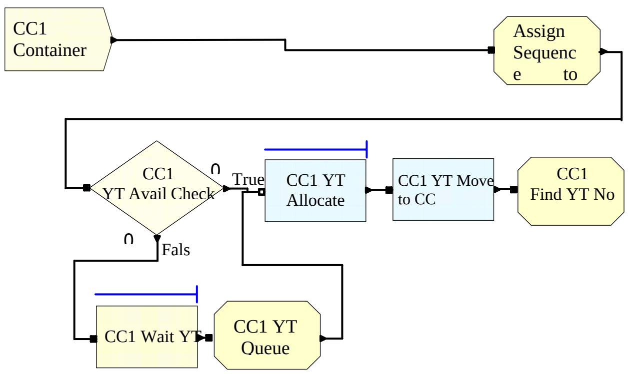

Fig. 5 Available Y/T after job completion of C/C

Table 2 Transporter module

	Name	Units	Type	Distance Set	Velocity (m/h)	Initial Position Status
1	CC1 Y/T	5	Free Path	CC1 Y/T Distance	10	CC1 Station
2	CC2 Y/T	5	Free Path	CC2 Y/T Distance	10	CC2 Station
3	CC3 Y/T	5	Free Path	CC3 Y/T Distance	10	CC3 Station

Secondly, if Y/Ts are assigned, the corresponding containers will be loaded on the Y/Ts, and move to the T/Cs. At this time, the moving distance of Y/T becomes the movement line's distance to the destination. If T/C is under work, Y/T has to wait (Fig. 6) At this point, the moving distance of Y/T is measured by a distance module (Table 3).

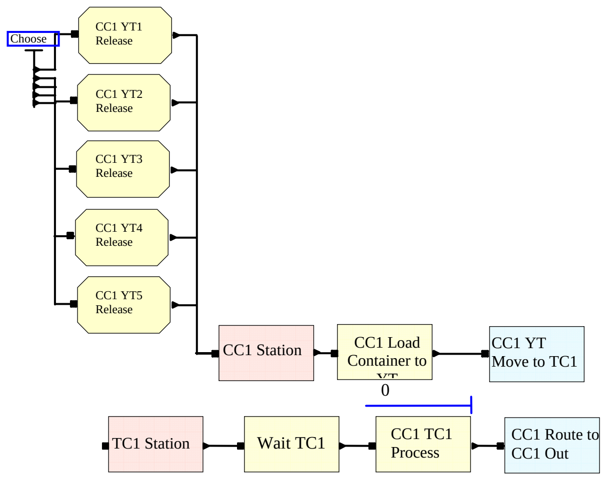

Fig. 6 Y/T moves to T/C

Table 3 Distance module

	Distance Module Name	Beginning Station	Ending Station	Distanc (Meters
1	CC1 Yard Tractor. Distance	CC1 Station	TC1 Station	378
2		TC1 Station	CC1 Exit	621
3	CC2 Yard Tractor. Distance	CC2 Station	TC2 Station	351
4		TC2 Station	CC2 Exit	486
5	CC3 Yard Tractor. Distance	CC3 Station	TC3 Station	621
6		TC3 Station	CC3 Exit	297

Finally, if T/C's storage work is over, Y/Ts will be released, and containers handling will also be ended (Fig. 7).

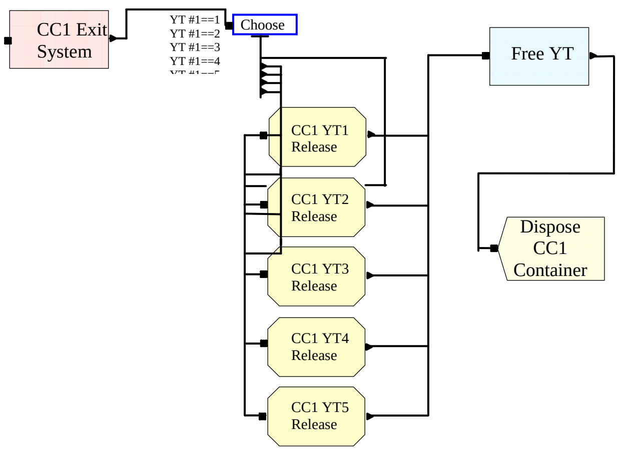

Fig. 7 If T/C's storage work is over, Y/T is released.

If the above-mentioned modules are connected, the modeling for one berth is completed. And this modeling is used for the programming of the container terminal with three berths. A new (or To-Be) model is similar to the As-Is model, but the difference is that Y/T is not assigned to a specific G/C and also that if Y/Ts are free, they are to be assigned to the nearest G/C. Fig. 8 illustrates the difference between the two model.

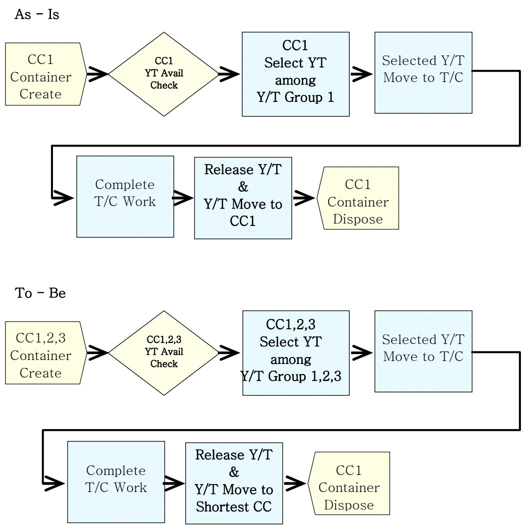

Fig. 8 Difference between the As-Is model and the new model

5.2 Test and Results

In order to enhance the readability of simulation, animation has been made. Also, for easy understanding of Y/T's flow, the animation has been expressed as shown in the Fig. 9. Replication has been made 100 times, and major output variables have been stored in the excel sheet by using VBA (visual basic for applications), and average values have been compared. In case of a As-Is model, it shows that 5 Y/Ts are sequentially assigned to C/C of one unit, and also shows the waiting queue of Y/Ts. In case of a new model, it illustrates that 15 Y/Ts for three C/C are automatically assigned according to resources conditions and shortest distance.

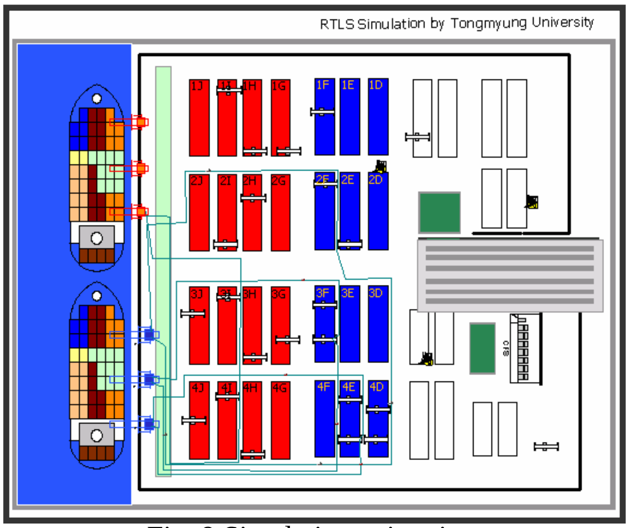

Fig. 9 Simulation animation

As a result of this test, the major output values of both the As-Is model and the new model are as follows Table 4.

Table 4 the Major Output Values

Output variables	Unit	As-Is model	To-Be model
Total handling volume	TEU	870	1,100
Handling volume per Y/T	TEU	58	73
Avg. Delay Time of C/C in Y/T waiting	Minutes	1.6	0.8

Fig. 10 shows the status of throughput according to time progress and Fig. 11 shows the relationship between delay time and throughput.

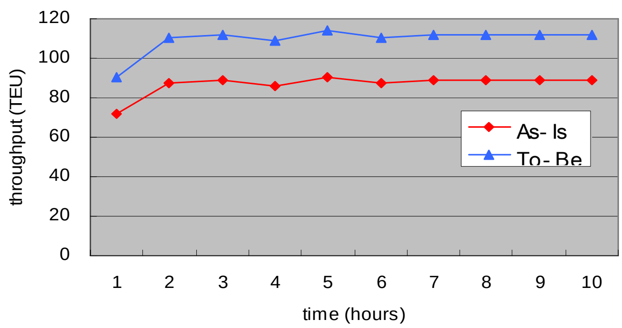

Fig. 10 The Status of Throughput according to Time Progress

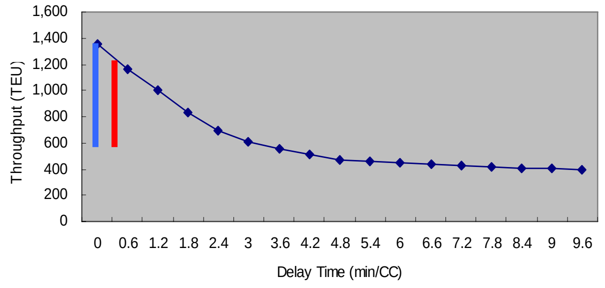

Fig. 11 The Relationship between Delay Time and Throughput

6. Conclusion

As a result of our research, it has been found out that the dynamic resources assignment of horizontal transfer equipment based on real-time locating data can raise productivity by more than 25% over the current batch and sequential assignment method. If an error range is reduced by using RFID technology, and also if RTLS is applied not only to the horizontal transfer equipment, but also to the yard cranes and containers, much 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 this end, RTLS technology is coming to the fore. In this respect, this study is expected to make a contribution to the introduction of RTLS.

However, this study has a few limits. As dynamic operation of transfer equipment have a positive effect on container unloading, simulation of this study has been confined to container unloading, and so pooling has also been limited to the ship alone. In this sense, it is not completely safe to say that this study has shown enough proof for the efficiency of a whole container terminal. Also sensitivity analysis on output variables has not been made enough, thus being unable to suggest diverse alternatives. From now on, we will make much more researches in these fields.

Acknowledgement

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[1] Y/T operation method has changes from existing working method by team to dynamic vehicle assignment, so that it can enhance the availability of equipment

2 Operation method of transfer equipment conducting loading and unloading simultaneously