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A Simulation Model for Improving the Productivity of Container Handling in the Container Terminal

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Abstract : *The productivity of container terminal is determined by its various operation methods. This paper aims at finding out the factors to enhance the productivity of container handling of quay crane, using simulation technique. Three levels of decision making in terminal operation, strategy, and tactics and operation are selected for defining parameters of simulation. The result of the simulation and test shows that the significant factors to improve the productivity are the stack height of container, block dispersion and the distance in yard planning for shipment. Decision making in the operation level, however, is of significance in the mixed condition of strategic and tactical level. The result shows meaningful guidelines in decision making under strategic, tactical and operation level.*

Key words : *Simulation, Handling, Productivity, Container, Terminal*

1. Introduction

Busan port has handled approximately up to 9,430,000TEU in 2002. Despite current remarkable achievements, the productivity of shipment per ship per hour is not as high as that of other ports such as Tokyo, Hong Kong, Rotterdam and Singapore. In the case of PECT(Pusan East Container Terminal) in Korea, the productivity of container handling equipment has reached 25.9 moves per crane per hour, whereas that of Singapore port can manage 33~40 moves per crane per hour[1),2)]. Other terminal's handling performances are as follows.

The causes of low productivity researched by one of the container terminals inside staff members are as follows.

- The variance of stacking area for shipment is large
- The long distance of specific container stacking area from shipside
- Not enough yard tractors available for a quay crane during peak time
- Frequent re-handling due to high stacking

This paper aims at finding out how to improve the productivity of container handling in the terminal, using simulation technique and statistical technique.

Table 1 Vessel handling performance records for handling large vessels

Terminals	Vessel handling (mvs/ship/hr)	Remarks
PSA, Singapore	232	2728 TEU ship in 2000
HIT, Hong Kong	236	with 7 cranes
Modern Terminals, Hong Kong	336	with 7 cranes

Source : Connekt(2001), Nethlerlands

2. LITERATURE REVIEW

In order to improve the port operation, it is necessary to apply various approaches to terminal like management science, simulation technique, automation technique and information technique. As the kinds of technique to solve the problem in port efficiency is too enormous, a few related papers are selected and reviewed in this paper.

Chen(2003) surveyed the literature on yard management

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1) Both in Asia and Europe, main shipping lines demand a high and reliable performance of terminals. According to interviews with terminal operators in Singapore, Malaysia, Hong Kong and Rotterdam, we can find that a berth performance of 100-150 moves/ship/hr is currently considered acceptable, that a berth performance will be increased in the future for the larger vessels to moves/ship/hr
2) Connekt, International state-of-the-art in container logistics and performance requirements for mega hubs, 2001.

and gave critical review and a comparative study on various decision problem that arise at container terminal and in most case, the solution to which go into making up the overall terminal management system. Through the survey, Chen concluded that most of the related studies have been found to be analytical modelling based of simulation modelling based.

As a few literatures using analytical modelling technique to improve the efficiency of container terminals, we will review Kim and colleagues's researches. Kim et al.(1999) tried to minimize the total travel time of straddle carrier to improve the productivity of container terminal. The authors tried to solve the routing problem by using integer programming technique. In addition, an efficient optimizing algorithm was also developed for solving routing problem of straddle carrier. Kim et al.(1998) suggested a decision support system to improve the efficient operation of port container terminals. This type of papers is to apply the mathematical technique to solve some fractional problems occurring in container terminal under some assumption. This approach is bounded to a problem of limited area in stead of broad view of container yard operation such as planning, operation and controlling.

Besides, there are a wide range of papers devoted to different aspects of port container terminal simulation. Kia et al.(2000) developed a computer simulation to compare the different operational systems- a container terminal equipped with electronic devices versus a terminal without such device. Although this paper give us insights concerning the importance of information technology and its role in improving the operation system in container handling, the target of assertion is limited to the relationship between operation efficiency and information technology.

Merkuryev et al.(1998) discussed the key issues of the application of modeling and simulation for management of the Riga Harbour Container Terminal with the project. Its objective is to improve logistics processes at RHCT. This paper hints that simulation is the best solution to improve logistics at container terminal.

Razman and Hussain at al(2000) modeled the quay cranes allocation, the resources allocations and the scheduling of the different operations and simulated it and analysed the result to maximize the performance of the port. The simulation method of the paper is helpful to solve the complex problems in container terminal. Noting the boundary of the paper, its purpose is to reveal the evaluation of the capability like prime mover, crane and berth, and also give some alternative for terminal configuration to improve port efficiency.

Koh et al.(1994) designed container terminal to object based simulation and combined with decision support system. Park et al.(1987) modeled Alabama Mobile Port using Monte Carlo type and analyzed using SLAM.

A simulation model is said to be a useful tool to determine best strategy and operational policies. So, we find out the main factor or factors affecting productivity, it is necessary to take two steps for a test. One is simulation technique the other is statistical test.

3. FACTORS FOR IMPROVING TERMINAL PRODUCTIVITY : THE CASE OF PECT

The Pusan East Container Terminal Co. Ltd(PECT) is a typical container terminal in Korea. PECT handles 1,500,000 TEU per year. The resources of PECT are shown in Table 2.

Table 2 The resources of PECT

Facility and Capacity	Particulars
Storage capacity	39,000TEU
Number of berths	4
Container Cranes(C/C)	11 units
Transfer Cranes (T/C)	32 units
Yard Tractors (Y/T)	73 units

Source : Pusan East Container Terminal Co., Ltd(PECT)

The yard in PECT is divided into two: 25 export blocks and 23 import blocks. The containers for loading are stacked on export block, whereas the containers for unloading on the import block by yard truck from ship. The layout is described as in Fig. 1.

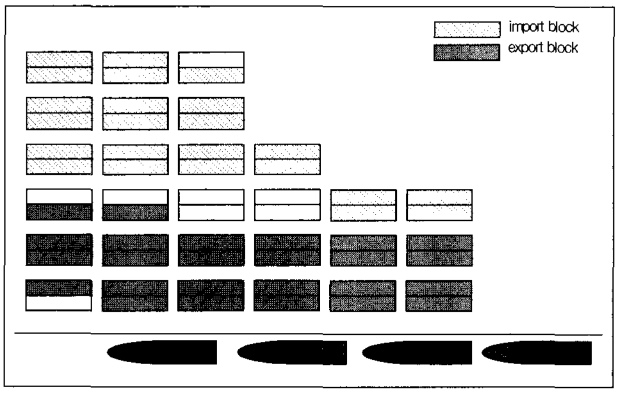

Fig. 1 The yard layout in the PECT

The productivity of container terminal depends on the yard arrangement. If the container for loading is close to the berth at which the ship is moored, the container handling time can be shortened. In addition, if it goes beyond optimal number of blocks for stacking shipment containers, the productivity of container terminal will lower. Therefore, both the optimal selection of blocks for stacking containers and the rearrangement of the block structure for either import or export containers are the major factors in productivity.

Container terminal is not only a place for container loading and unloading but also for receipt and delivery through the gate. Therefore, terminal management system consists of ship operation system, cargo moving system, storage systems, receipt and delivery systems, gate operation systems, and management and operation information system. This operation procedure and systems have been used as general models regardless of the size or location of container terminals. The PECT adopts a transfer crane and yard truck system for yard handling. A yard crane handles stacking and picking up containers on the stack. The containers among yard crane, yard truck and container crane are transported in sequence.

The productivity must be focused on the following two key points. Firstly, the delay time of container crane caused by late arrival of yard truck under ship must be reduced. The other is accrued by inflexibility, the capability providing for enough yard trucks during peak time

Secondly, in relation to the productivity, the free time system, which doesn't have to pay for storage charge during 10 days in case of PECT, has a strong influence on yard handling productivity. Long free time has resulted in a higher stacking or lowered the utility of yard space. Generally speaking, if the container stacking height is lower, the number of container re-handling will be reduced.

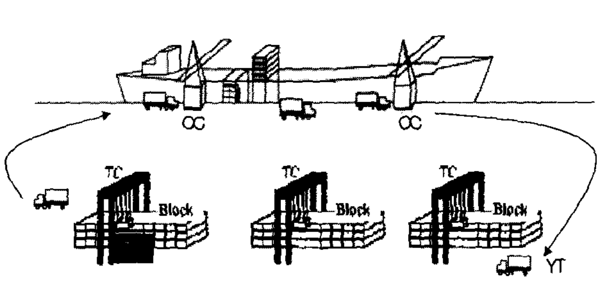

Fig. 2 Terminal handling operation

4. SIMULATION MODEL OF TERMINAL OPERATION

4.1 Building Simulation Model

Most complex, real-world systems with stochastics cannot be accurately defined by a mathematical model, which can be evaluated analytically. Thus, a simulation is often used for investigation area(Law et al., 1982). The idea of a system is placed in the center of any simulation study (Graybeal et al., 1980). A system can be defined more broadly than a collection of physical objects and their interactions. In our case, a container terminal is considered to be a system, and its operations and interactions as the collection of objects.

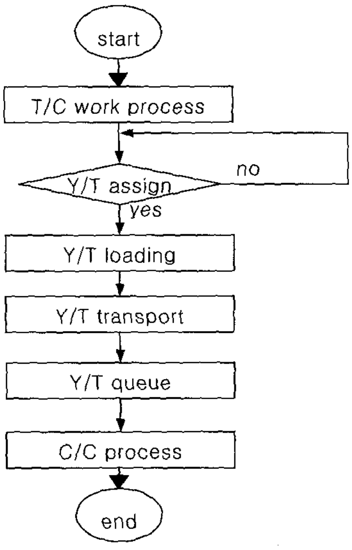

Fig. 3 Workflow of container handling

The ARENA, 4th version (Kelton et al.,2001), is used to simulate. The reason for utilizing this simulation package is that it has some strong points for modeling the process such as ship arrival and queuing, container crane and yard tractor service pattern, etc.

The scopes of the simulation include only container shipment handling on the yard and vessel. The process of container handling on the yard is shown in Fig. 3. If the simulation starts, the simulated transfer crane works for container handling in the yard and waits until next job. As next job, the waiting yard truck receives the shipment and transports it to container crane. Last, container crane handles the shipment for loading on the vessel.

To design the simulation model, the entity and its attributes are to be defined. As the entities for simulation, transfer crane, container crane and yard truck are chosen as below in the table 3. The data relates to entity activity already published in the paper(Yun et al., 1998). Both of the processing distribution of container crane and transfer crane are normal distribution with least square error. In the table 3, the processing time of transfer crane and container crane and the velocity of yard truck will be used for simulation.

Table 3 Simulation entities and its attributes

Equipment	T/C	C/C	Y/T
Velocity (km/h)	8.04	2.77	20
Processing time	N (87sec, 19.3sec)	N (112.8sec, 31.2sec)	Variable by distance

Source : Yun et al.1998

4.2 Definition of simulation parameters

In order to simulate, the parameters for simulation model are to be defined. To define parameters affecting the productivity, terminal operation should be described in a view of parameters in advance.

- To enhance the utility ratio of container crane, sufficient number of yard trucks must be supplied to reduce the waiting time of container crane. The parameter related to yard truck is the number of yard truck allocated for a quay crane.
- The extent of dispersion with which containers for shipment are stacked on different blocks can be chosen as a parameter.
- As the performance of transfer crane affects the terminal productivity, its processing time can be chosen a parameter. The processing time relates to the average height of container stacks on the yard. As the height of stack is higher, the number of handling , processing time will increase.
- Lastly, as yard blocks for inbound container or outbound container affect the productivity, yard disposition can be chosen as a parameter.

The initial value for simulation is as follows:

- Time for ready to simulate (minute): 5 minutes
- Recurrence number for simulation: 10 times

In summary, four parameters - dispersion extent of container stack, yard distance, number of yard trucks and the processing time of transfer crane - are defined.

Furthermore, in order to measure the effect of simulation to improve, the base point to compare parameters is to be established. In this research, the current operation status of PECT in 2002 is selected as a base point as shown in the section 2 of table 4. The value of parameter is also to be defined for simulation as in the section 3 of the table. For example, 2 blocks are supposed to be used for loading space in PECT as a base point. Particularly, the value of T/C processing time is set for 60sec and 110sec, it just shows to the processing time according to free time.

Table 4 Simulation parameter and its value

Parameter	Current value as base point	Value for simulation
Dispersion extent	2 blocks per a quay crane	1 block per a quay crane 3 block per a quay crane
Yard distance	300 m	200m 400 m
Number of yard truck	4 per a quay crane	5 per a quay crane 6 per a quay crane
T/C processing time	N (87, 19.3)	N (60, 15) N (110, 25)

To facilitate the understanding of simulation procedure, the layout of simulation model made by ARENA tool is suggested as in Fig. 4.

The above parameters are repeatedly simulated 10 times while loading same figures of containers.

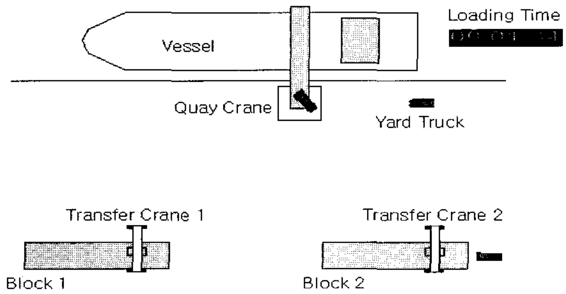

Fig. 4 Simulation animation by ARENA

5. RESULTS OF SIMULATION

To find out the main factor or factors affecting productivity, it is necessary to take two steps for a test. One is simulation technique the other is statistical test. Whether or not the parameter is of significance to improve the productivity was tested by ANOVA using MINITAB release13. Significant level to reject null hypothesis is set to 0.05.

Using the simulation model made by ARENA software package, four cases can be simulated.

(1) Under the constant conditions of the parameter in tactical and operation level, strategic parameter can be simulated and tested.

(2) Under the constant conditions of strategic and tactical parameters, operation parameter can be simulated and tested.

(3) Under the constant conditions of strategic, two tactical parameters can be simulated and tested

(4) Varying strategic and tactical parameter, finding optimal operational decision can be simulated and tested

5.1 First case test

Under the assumption that lower height will reduce the process time of transfer crane, the result of simulation against the different value of strategic parameter is shown in Table 5 and Fig. 5. This simulation results were used for input data of one-way ANOVA. The test result under a 95% reliability level is that the speedup of transfer crane has direct relation to the improvement of productivity (see Table 5)

Table 5 One-way ANOVA according to T/C processing time

One-way ANOVA: TC60, TC87, TC110

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	2204166	1102083	5.23	0.012
Error	27	5686994	210629		
Total	29	7891160			

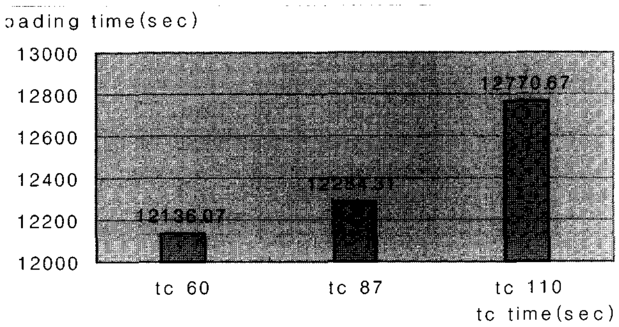

Fig. 5 Comparison of loading time on T/C processing time

5.2 Second test

Under the constant conditions of strategic and tactical parameters, one operation parameter with which the number of yard truck per crane before starting the container crane was simulated and tested. The results from different value of operation parameter are shown in Fig. 6 and Table 6. This simulation results were used for input data of one-way ANOVA. The test result under a 95% reliability level is that the number of yard tractor does not have direct relation to the enhancement of productivity (see Table 6).

Table 6 One-way ANOVA according to the number of yard truck

One-way ANOVA: YT4, YT5, YT6

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	218897	109449	0.62	0.543
Error	27	4729064	175151		
Total	29	4947961			

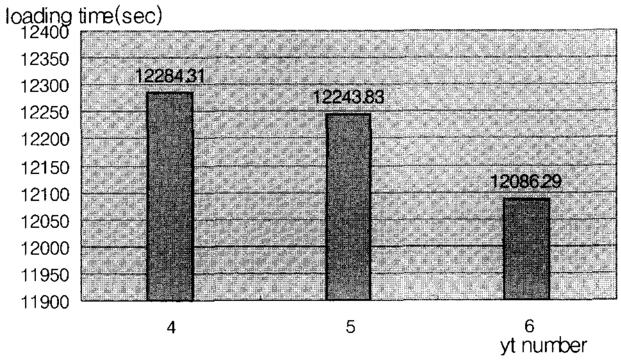

Fig. 6 Comparison of loading time change according to the number of Y/T

5.3 Third case test

Under the constant conditions the constant is the value of base point reflecting operation status in PECT of strategic, two tactical parameters was simulated and tested. Under the constant conditions of strategic and operation parameters, the results from different values of tactical parameters such as remoteness and dispersion are shown in Fig. 7 and Table 7.

According to the test result, the ANOVA from two parameters has interaction each other. This interaction between remoteness and dispersion has direct relation to the improvement of productivity in the test with a 95 % reliability level(see Table 7)

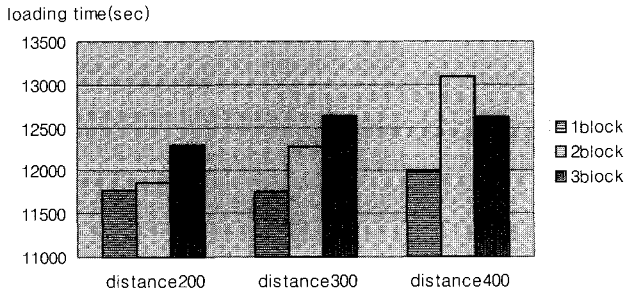

Fig. 7 Two-way ANOVA according to yard remoteness and dispersion

Table 7 Two-way ANOVA according to yard remoteness and dispersion

Two-way ANOVA: C3 versus block, distance

Analysis of Variance for C3

Source	DF	SS	MS	F	P
Dispersion	2	8016813	4008407	19.71	0.000
Remoteness	2	5147607	2573803	12.66	0.000
Interaction	4	3648256	912064	4.49	0.003
Error	81	16469684	203329		
Total	89	33282361			

Table 8 The result of ANOVA

Source	DF	SS	MS	F	P
Block	2	3786631	1893315	2206.33	0.000
Distance	2	7291279	3645639	4248.36	0.000
TC	2	4938317	2469158	2877.38	0.000
YT	2	514304	257152	299.67	0.000
Block*distance	4	3601229	900307	1049.15	0.000
Block*TC	4	1748169	437042	509.30	0.000
Block*YT	4	128540	32135	37.45	0.000
Distance*TC	4	1758321	439580	512.25	0.000
Distance*YT	4	68461	17115	19.94	0.000
TC*YT	4	27897	6974	8.13	0.001
Block*distance*TC	8	1955176	244397	284.80	0.000
Block*distance*YT	8	13652	1706	1.99	0.115
Block*TC*YT	8	15884	1985	2.31	0.073
Distance*TC*YT	8	12548	1569	1.83	0.145
Error	16	13730	858		
Total	80	25874138			

5.4 Fourth test

Fourth case handles the environment in which four parameters vary freely within limited value without constant constraints. To show simulation result in this paper is difficult because of multi dimension. However, the test result is shown in Table 9.

The result of the above test shows that the dispersion and remoteness of yard and the process time of transfer crane have interaction one another. The implication of this test is that yard planning and the height of stack have positive influence on the enhancement of productivity.

Besides the above test result, new fact about operation plan is to be found out. That is to find out the significant number of yard trucks to improve productivity under various strategic and tactical situations. This result was derived from simulation.

6. Conclusion

This paper aims at finding out the main factor to improve the productivity in container terminal. In order to solve the problem, two-step methods of simulation and statistics test were used.

The result of the simulation and test shows that significant factors in productivity were the stacking height of container, block dispersion and distance in yard planning for loading. However, the decision making in operation level is of significance in the mixed condition of strategic and tactical level.

Although the result shows the meaningful guidelines in decision making under strategic, tactical and operation level, it has some limitations in applying to the container field. In addition to the above results, other factors to improve the productivity are required to be considered: the skill of labour for container handling ar shipside, the status of work preparation, accurate information of container to enter or leave the gate. Futhermore, we have a limitation in setting value, that is, the T/C processing times such as TC 60, TC110 we have used for simulation as parameters is assumption value. This kind of value assumption are to be revised in order to make the more correct decision while reflecting realistic operation. Those limitations for this study has to be considered in next study.

Table 9 The loading time according to each station

		TC 60			TC87			TC 110		
		YT4	YT5	YT6	YT4	YT5	YT6	YT4	YT5	YT6
1 block	distance200	11727.13	11696.37	11728.97	11769.61	11732.4	11766.45	11883.97	11811.85	11879.3
	distance300	11752.72	11622.65	11653.55	11756.21	11825.22	11768.49	12511.78	12460.75	12462.62
	distance400	11929.13	11875.9	11863.36	11984.27	11891.15	11889.17	12795.42	12550.72	12533.05
2 block	distance200	11745.53	11711.87	11614.59	11856.69	11774.77	11721.45	12189.81	12046.55	11990.4
	distance300	12136.07	12069.67	11953.51	12284.31	12243.83	12086.29	12770.67	12667.24	12569.49
	distance400	12675.44	12531.9	12347.51	13083.14	12832.03	12632.18	14643.96	14417.28	14276.34
3 block	distance200	11918.7	11808.73	11732.89	12299.39	12126.2	12064.62	12544.95	12222.67	12273.31
	distance300	12654.79	12541.52	12390.63	12642.33	12573.8	12380.31	12335.68	12093.08	12113
	distance400	12557.89	12336.46	12236.65	12610.35	12333.65	12298.65	12986.73	12625.82	12693.98

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