A STUDY ON THE OPIMAL CONFIGURATION OF BERTHS USING SIMULATION
-BASED ON THE WHARF IN GWANGYANG PORT-

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ABSTRACT

A port is an important asset of the country and a national facility requiring lots of budget. Presently, approx. 900 berths of 31 ports are in operation in Korea and about 1 trillion Won is required for building the ports each year. The purpose of this study is to evaluate the appropriateness of berth configuration of the port and also evaluate whether scale of the berth built on the basis of estimated cargo volume at time of construction shall be still appropriate after a significant length of time. This study targets 11 steel berths of Gwangyang Port and desires to evaluate if configuration and scale of such berths are properly supporting the cargo handling. In order to evaluate configuration of the steel berths in Gwangyang Port, the author has collected Port-MIS data from 2011 to 2013 and analyzed the data for 3,591 cargo handling events out of 3,687 events except 96 events which did not intend to load or unload cargo.

According to result of the optimal berth configuration using Arena Simulation, a configuration with 7 berths was proved to be the optimal configuration. That is, building 1 berth of class 50,000 ton, 3 berths of class 30,000 ton, 2 berths of class 5,000 ton and 1 berth of class 3,500 ton was confirmed to provide an efficient operation and service.

It is expected to have an effect of saving national expenses by planning an optimal berth configuration in development of the berths through cargo volume estimation by establishing an optimal operation system through this study.

Keywords: Arena, Simulation, Gwangyang Port, Berth Optimal Design, Cargo Capacity, Waiting ratio

1. INTRODUCTION

The port is an important national asset which supports distribution of export and import cargos and is also a national facility requiring lots of investment.

Efficient use of the port is an important matter in view of cost saving. In Korea, about 900 berths are in operation in 31 ports and approx. 1 trillion Won is required for construction of the port every year.

The function of the port changes continuously according to purposes of background industrial zones. For example, even the berth which was developed as a general merchandise berth in early time shall change its purpose to handle steel products if the enterprises which produce ship blocks are located in the background site of the port. With such a reason, efficient use of the berth is available only when the port function is adjusted to business change every year.

A problem concerning configuration of appropriate berths is that it would cause a tremendous economic loss if the scale of berth is too big comparing with cargo volume handled in the berth due to overestimated cargo volume at time of building the berth.

The goal of this study is to evaluate the appropriateness of berth configuration of the port. That is, it shall evaluate if scale of the berth built on the basis of estimated cargo volume at time of construction would be still appropriate after passing a significant length of time. This paper targeted 11 steel berths of Gwangyang Port. Thus, the ultimate goal of this study is to figure out an optimal berth configuration by evaluating whether the configuration and scale of the steel berths support the cargo handling appropriately.

The purpose of this study is to evaluate the appropriateness of present berth configuration targeting steel berths of Gwangyang Port, thus this study needs to develop a simulation program which may demonstrate the ships entered, movement, docking, loading and unloading and departure of the ships. The simulation model shall support 11 berths and describe number of ships and cargo handling volume of the berths exactly. Occupation and Waiting ratio of the berth shall be calculated as for evaluation criteria of berth performance. An appropriate berth configuration has a purpose to figure out the optimal berth configuration required for handling the present cargo volume and shall satisfy an appropriate occupancy ratio and allowable Waiting ratio. In order to achieve the goal of this study, a method which may check whether the berth configuration satisfies an appropriate occupancy ratio through repeated simulation tests by eliminating the berth which lacks cargo handling capacity is used. Following 3 procedures shall be used in order to figure out the optimal berth configuration:

The 1st procedure is to design a simulation system which may represent the ships entered and cargo handling of the ships appropriately, and to verify if such simulation system developed describes the present situation well enough.

The 2nd procedure is to figure out what kind of berth configuration would meet an efficient occupation and waiting ratio of the berth which are the evaluation criteria after completing the verification of such validity.

The 3rd procedure is to verify if the present situation could be properly dealt with even when the number of berths decreased by adjusting number of berths

This paper intends to verify that even such decreased number of berths shall be able to handle the present cargo volume smoothly by finding out an appropriate scale and number of berths through above 3 procedures.

2. LITERATURE REVIEW

There are several the results to apply the simulation method to find PPI of port terminals. Legato and Mazza (2001) focused on the berth and allocation of berths to arriving ships with queuing network based on the model which is simulated by Visual SLAM software in various scenarios. Their model was tested with data from Gioia Tauro container terminal. Key issues of the application of modeling and simulation for the management of the Malaysian Kelang container terminal are discussed in paper by Tahar and Hussain (2000). Nam et al. (2002) examined the optimal size of the Gamman Container Terminal in Busan, in terms of berths and quay cranes using the simulation analyses which were performed in four scenarios, representing different operational patterns. Shabayek and Yeung developed simulation model employing the Witness program to analyze the Hong Kong's Kwai Chung container terminal performance. It is shown to provide good results in predicting the actual operation system of the terminal. Kia et al. (2002) investigated the role of computer simulation in evaluating the container terminal performance in relation to its handling techniques and their impact on the capacity of terminal. Pachakis and Kiremidjian (2003) presented a ship traffic modeling methodology based on statistical analysis of container ship traffic and cargo data obtained from a port in the United States. Sgouridies et al. (2003) focused on the simulated handling of incoming containers. Results on the service level, i.e., service times, utilization factor, and queues, are generated for analysis. Demirici (2003) developed simulation model to analyze port operations and was run especially for investment planning. This paper discussed the simulation model results of Trabzon port. Bielli et al. (2005) proposed simulation model which can improve ports efficiency and they gave the architecture components that are implemented with Java. Simulator calibration and validation were also presented in the paper at the Casablanca container terminal. van Renzburg et al. (2005) described a computer simulation model of ocean container carrier operations. Their simulation is called SimSea. Ali Alattar et al. (2006) simulated different condition to find out the queue of containers at the port and also analyses the effect of increase in the facilities at the port to reduce this queue. Dragović et al. (2005a) gave the simulation model results for ship berth link of the Pusan East Container Terminal (PECT). They developed simulation model which can be used by the port management to improve different operations included in the process of ship service at the ship-berth link. Dragović et al. (2005b) developed simulation models of ship-berth link with priority service in container port. The ship berth-link performance for five alternative strategies was evaluated, and system behavior observed. The results revealed that simulation modeling is a very effective method to examine the impact of introducing priority, for certain class of ships, on the ship-berth link performance at PECT.

3. PORT FACILITY AND CARGO HANDLING SITUATION OF STEEL BERTHS OF GWANGYANG PORT

1) Port Facility Situation of Steel Berths

Steel berths of Gwangyang Port consists of total 11 berths including 1 berth of 50,000 ton class, 3 berths of 30,000 ton class, 1 berth of 20,000 ton class, 5 berths of 5,000 ton class and 1 berth of 3,500 ton class.

The depth of water is 14 m for 50,000 ton class, 12m for 30,000 ton class, 11m for 20,000 ton class and 7 m for 5,000 ton and 3,500 ton class.

The length of quay of each berth is 280m for 50,000 ton class, 240m for 30,000 ton and 30,000 ton class, 126.6m for 5,000 ton class and 107m for 3,500 ton class and all of 11 berths handles steel products.

Details are specified on <Table 1>.

<Table 1> Facility Situation by Berth of Steel Terminal of Gwangyang Port

Terminal	Berth No.	Docking Capacity	Depth of Water(m)	Length (m)	Handling Cargo
Steel Terminal	41	50,000	14	280	Steel Products (HR, CR)
	42	30,000	12	240	
	43	30,000	12	240	
	44	30,000	12	240	
	45	20,000	11	240	
	46	5,000	7	126.6	
	47	5,000	7	126.6	
	48	5,000	7	126.6	

	49	5,000	7	126.6	
	4A	5,000	7	126.6	
	4B	3,500	7	107	

2) Number of Ships by Size by Berth

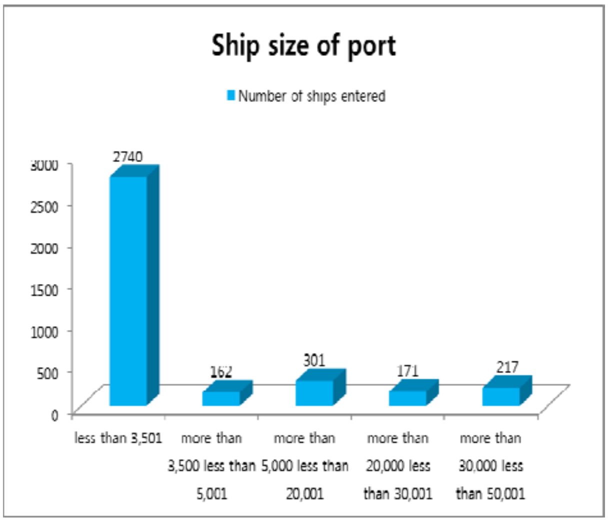
The author has collected Port-MIS data of steel terminal of Gwangyang Port for 2011 –2013 in order to find out number of ships entered and DWT (Dead Weight Tonnage) and the average value for 3 years shall be used in this paper. The items of the data collected include port name, terminal name, berth name, ship name, ships entered date and time and total tonnage.

Total number of data collected is 3,687 data of ships entered and departure for 3 years, but 96 data which did not handle the cargo, for example refueling, repair, commodities for ship, crew shifting and others were excluded.

<Table 2> Number of ships entered and cargo volume handled

Berth name	Specification and operation situation of the terminal				
	Berth length (m)	Depth of water (m)	Berth size (DWT)	Number of ships entered	cargo volume handled
Berth 41	280	14	50,000	243	4,221,687
Berth 42	240	12	30,000	391	4,691,573
Berth 43	240	12	30,000	345	1,893,038
Berth 44	240	12	30,000	842	1,177,284
Berth 45	240	11	20,000	447	1,456,745
Berth 46	126	7	5,000	360	1,075,221
Berth 47	126	7	5,000	268	844,858
Berth 48	126	7	5,000	258	946,662
Berth 49	126	7	5,000	223	715,460
Berth 4A	126	7	5,000	12	30,336
Berth 4B	107	7	3,500	202	566,648

The size of ships were classified to below 3,500 ton class, over 3,051 ton below 5,000 ton class, over 5,001 ton below 20,000 ton class, over 20,000 ton below 30,000 ton class and over 3,0001 ton below 50,000 ton class based on steel of port, and total 3,591 ships have entered and departed for 3 years.



[Figure 1] Ship size of port

4. SIMULATION MODELING

1) Outline for development of simulation system for ship entered

It needs a simulation which may describe the reality of ship entered as well as cargo handling in order to measure the evaluation criteria for 11 berths of steel terminal of Gwangyang Port, such as cargo handling volume, waiting ratio, occupancy ratio and number of ships. Thus, in this section, this paper intends to design a simulation model which may describe situation of the reality well enough.

☐ Definition of waiting ratio

The waiting ratio in port means that the ships arrived at the terminal wait for cargo handling due to lack of berths and waiting ratio is obtained by dividing average waiting time by average service time.

☐ Definition of Berth occupancy ratio

The issue to utilize the berth at an appropriate level without waiting of the ship has a relation with arrival schedule of the ship. If the arrival schedule of the ship is well established, the waiting time of the ship shall be reduced and the occupancy ratio of the berth shall be significantly risen. However, such schedule become delayed due to unexpected bad weather during sail, the waiting shall occur due to other ships entering at the same time.

The berth occupancy ratio is calculated the ships berthing time divided by berth available time for a year. <Table 3> shows the relationship between average berth occupancy ratio and waiting ratio of major international ports. In the case of for 11 berths of steel terminal of Gwangyang Port, the criteria for finding optimal berth configuration is considered 65% of berth occupancy ratio and less than 9%.

<Table 3> Average berth occupancy ratio and waiting ratio [%]

Number of berth	Appropriate berth occupation rate	Container terminal		General terminal	
		Tw / Ts	Tw / Ts	Tw / Ts	Tw / Ts
		K = 4	K = ∞	K = 1	K = 2
1	0.40	0.42	0.33	0.67	0.50
2	0.50	0.22	0.18	0.33	0.26
3	0.55	0.14	0.12	0.22	0.17
4	0.60	0.12	0.10	0.18	0.14
5	0.65	0.12	0.10	0.17	0.13
6 or more	0.70	0.12	0.10	0.19	0.14

Average Waiting ratio= Average Waiting Time/Average Service Time(Tw / Ts)

: UNCTAD, 1986 and Hans Agerschou (2004), "Planning and design of ports and marine terminals", 2nd edition, Thomas Telford.

When number of berth is 1, appropriate berth occupancy ratio is 40% while average 33%-42% of ship waiting occurs. When number of berth is 2, appropriate berth occupation is 50% and average 18%-22% of ship waiting ratio occurs. When number of berth is 3, appropriate berth occupation is 55% and average 10%-12% of ship waiting ratio occurs. When number of berth is 4, appropriate berth occupancy ratio is 60% and average 10%-12% of ship waiting ratio occurs. When number of berth is 5, appropriate berth occupation is 65% and average 10%-12% of ship waiting ratio occurs. When number of berth is 6, appropriate berth rate is 70% and 10%-12% of ship waiting ratio occurs.

2) Design of port simulation modeling

Actual data collected of steel terminals were utilized in order to find an optimal model for 11 steel berths of Gwangyang Port. Arrival time interval of the ships, TPC (Ton per Call) by ship and handling time of cargo equipment per ton were selected as input variables of the simulation. Number of ships entered and handling tonnage of steel terminal for 3 years were used as for analysis data for the simulation.

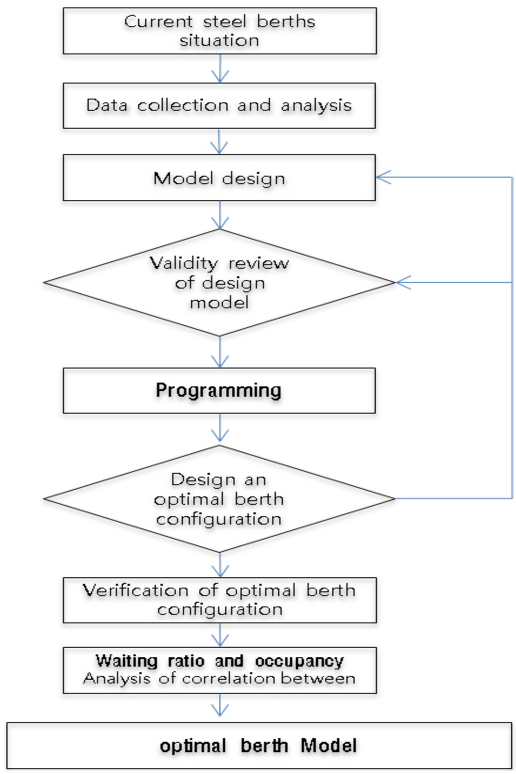
The simulation model was designed based on input data created. The information created from the simulation model includes cargo handling volume by berth, number of ships entered, waiting ratio and occupancy ratio by berth etc.

The actual number of ships entered and cargo volume handled from 2011 to 2013 were compared with those of simulation result in order to verify the validity of the simulation model.

When complete the validity verification of the simulation, check whether the berth configuration satisfies an appropriate occupancy ratio and allowable waiting ratio as varying the present berth configuration. If it does not satisfy the criteria, continue testing with a new berth configuration plan.

For a new berth configuration plan, use a method to reduce number of the berths. The berths targeted to be reduced shall be the berths where the least cargo volume and ships entered occur.

The flow chart for designing the simulation is shown on <Figure 2>.



[Figure 2] Simulation flow chart

☐ Input & Output Variable of Simulation Setting

The raw data were set as input variables after analysis in the simulation and output variables to be created through the simulation shall be set as <Table 4>

<Table 4> Major variables of quay simulation setting

Item	Variable	Description	Remark
Input variables	Ship arrival	Arrival interval time	Probability distribution
	Number of berth	Number of berths	11 berths
	Berth access time	Time from anchorage to arriving berth	Actual value
	Berth leaving time	Time from leaving berth to leaving port.	Actual value
	Idle time before	Time from docking to service	Actual value
	Idle time after	Time after service to leaving quay	Actual value
	Number of group1	Number of berths for Group 1	Two berth

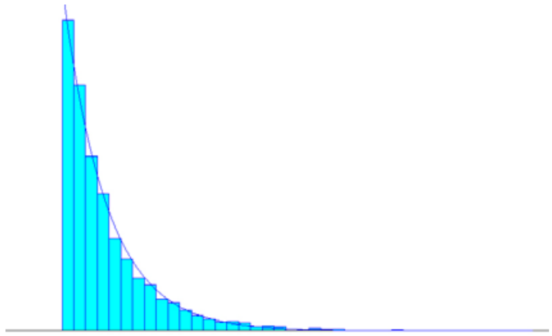
	Number of group2	Number of berths for Group 2	Four berth
	Number of group3	Number of berths for Group 3	Five berth
	Number of group4	Number of berths for Group 4	One berth
	Original no of ships	Actual number of ships entered	Actual value
	Original throughput of cargos	Actual cargo volume handled	Actual value
	Ship DWT	Distribution of ship Size occurrence	Probability distribution
	Sub TPC classify1	TPC assignment distribution	Percentage
	First class1	TPC occurrence distribution	Probability distribution
	Cargo handing time	Cargo handling time per 1 ton	Actual value
Output variables	Waiting ratio	ship waiting ration	Average ship waiting time ratio comparing to average ship docking time
	Occupancy ratio	Berth occupancy ratio	Docking time ratio comparing to ship docking available time
	Total no of ships berthed	Number of ships entered per 1 berth	Calculated value
	Total number of cargos handled	Cargo handling volume per a berth	Calculated value
	Entity number out	Number of ships which completed service	Number of ships departed port after completing service
	Ship queue TAVG	Average waiting time of the ships in queue line	Average ship waiting time
	Aver service time	Average service time in a certain berth	Calculated value
	VarShipProc1	Number of ships docked in berth No. 1	Calculated value
	Total varShipProc	Number of total ships entered	Calculated value
	Total throughput	Total cargo volume handled (ton)	Calculated value
	Avg wait Time group1	Average waiting time by Group	Calculated value
	Today	Date and time of today' Days to base time(TNOW)	Calculated value

□ Creation of Ship Arrival Interval Distribution

As result of the analysis of 3,591 ship's activity for three years, ship arrival interval distribution is expressed by <table 5> and <Figure 3>.

<Table 5> Ship Arrival Distribution of Steel Terminal of Gwangyang Port

Terminal Type.	Number of ships entered	Distribution Type	Distribution
Steel Terminal	3,591	Exponential Distribution	-0.001 + EXPO(7.31)



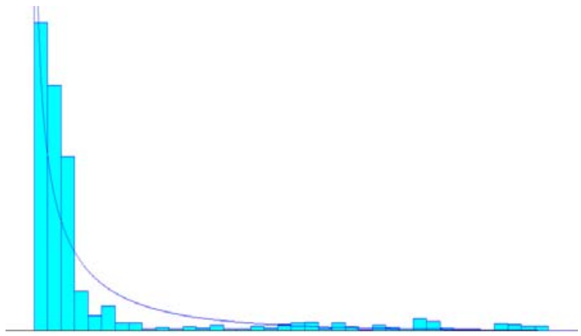
[Figure 3] Ship Arrival Distribution

□ Creation of Ship Size Distribution

As result of the analysis of 3,591 ship's size for three years, ship size distribution is expressed by <table 6> and <figure 4>

<Table 6> Size distribution of the ships entered the steel terminal

Terminal Type.	Distribution Type	Distribution
Steel Terminal	Weibull Distribution	36 + WEIB(4.38e+003, 0.681)



[Figure 4] Ship size Distribution

□ Creation of Cargo Volume Distribution by Berth

As result of the analysis of ton per call(TPC) of each berth for three years, TPC is expressed by <table 7> .

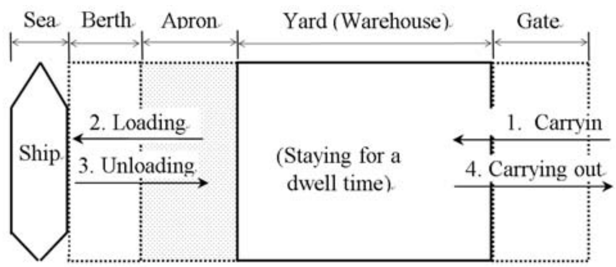
<Table 7> Function Formula of Estimation Distribution by Berth

Berth.	TPC1	TPC2	TPC3	TPC4
Berth 41	8 + 9.39e+003 * BETA(0.545, 1.4)	UNIF(1.02e+004, 3e+004)	3.01e+004 + 4.85e+004 * BETA(0.85, 2.4)	n/a
Berth 42	5 + 3e+003 * BETA(0.473, 0.827)	3.02e+003 + 1.2e+004 * BETA(0.478, 0.916)	UNIF(1.51e+004, 2.99e+004)	TRIA(3.04e+004, 3.36e+004, 6.3e+004)
Berth 43	7 + WEIB(546, 0.802)	TRIA(2.03e+003, 3.45e+003, 4e+003)	4.02e+003 + WEIB(2.42e+003, 1.26)	1.01e+004 + GAMM(1.37e+004, 0.676)
Berth 44	9 + 391 * BETA(0.971, 1.29)	410 + GAMM(50.7, 2.36)	820 + 2.18e+003 * BETA(0.86, 1.14)	3.1e+003 + WEIB(2.55e+003, 0.706)

Berth 45	16 + 1.98e+003 * BETA(0.185, 0.237)	2e+003 + 1.3e+003 * BETA(0.682, 0.391)	3.3e+003 + LOGN(1.19e+003, 5e+003)	6.04e+003 + EXPO(3.64e+003)
Berth 46	35 + 1.97e+003 * BETA(0.365, 0.283)	2.1e+003 + 1.1e+003 * BETA(0.709, 0.476)	3.22e+003 + ERLA(122, 2)	4.05e+003 + 9.97e+003 * BETA(0.803, 2.42)
Berth 47	16 + 1.98e+003 * BETA(0.392, 0.277)	2.05e+003 + 1.25e+003 * BETA(0.844, 0.47)	3.31e+003 + EXPO(215)	4.01e+003 + 4.59e+003 * BETA(0.76, 0.545)
Berth 48	TRIA(16, 1.89e+003, 2.4e+003)	2.57e+003 + 732 * BETA(0.677, 0.374)	3.31e+003 + GAMM(184, 1.14)	NORM(7.17e+003, 3.87e+003)
Berth 49	37 + 1.96e+003 * BETA(0.347, 0.348)	2e+003 + 1.3e+003 * BETA(0.707, 0.344)	3.3e+003 + GAMM(104, 1.16)	3.8e+003 + WEIB(812, 0.522)
Berth 4A	60 + WEIB(270, 0.338)	2.35e+003 + EXPO(1.92e+003)	n/a	n/a
Berth 4B	TRIA(20, 2.04e+003, 2.2e+003)	2.24e+003 + 1.06e+003 * BETA(0.853, 0.457)	3.3e+003 + 100 * BETA(0.842, 0.106)	3.4e+003 + WEIB(610, 0.566)

☐ Logic of the Model

The system was set as queuing system and designed as the events with a flow of ship arrival, assignment of ship size, berth assignment, TPC assignment by berth, cargo handling time per 1 ton and departing the port after loading service <figure 3>.



[Figure 5] Flow of quay simulation

5. VERIFICATION AND VALIDITY OF SIMULATION MODEL

It needs to verify if the simulation designed by this paper reflects the reality in order to figure out the optimal berth configuration.

For verification, the author conducted verification through developing anchorage-berth-yard link simulation model and checking ship arrival, queuing in case of berth occupied, cargo handling and ship leaving activity and simultaneously yard stocking and leaving activity.

After verification task, the authors try to validate simulation model through checking accuracy ratio between the actual data and the result values of simulation for 3 years. The results of actual data and simulation are as follows:

<Table 8> Validity Test Result of Simulation

Terminal Name	Data of calling ship and cargo handling of Steel Terminal for 3 years		Simulation Result				Accuracy Ratio	
	Number of ships entered	Cargo Volume handled	Number of ships entered	Waiting ratio (%)	Occupancy Ratio (%)	Cargo Volume Handled	Number of ships entered	Cargo Volume handled
Steel Terminal	3,591	17,619,512	3,584	2.3%	46%	16,920,385	99.8%	96%

The simulation of this study premised that all 11 berths of the steel terminal operate simultaneously and intended to verify the simulation by number of ships entered and cargo volume handled of the whole terminal.

Total 3,591 ships entered the steel terminal for 3 years and the cargo volume handled was 17,619,512 ton. According to simulation result, total 3,584 ships was entered the steel terminal and cargo volume handled was 16,920,385 ton. The accuracy ratio shows 99.8% for number of ships entered and 96% for cargo volume handled.

The simulation could not show the correct matching ratio because number of ships entered and cargo volume handled may cause an event as distribution but reflects the reality within ±5% error range.

6. PROPOSAL OF AN OPTIMAL BERTH CONFIGURATION

Now, there are 11 berths in the steel terminal consisting of 1 berth of 50,000DWT class, 3 berths of 30,000DWT class, 1 berth of 20,000DWT class, 5 berths of 5,000DWT and 1 berth of 3,500DWT class.

Number of ships entered and cargo volume handled for 3 years in 11 berths are as <Table 9>.

<Table 9> Number of ships entered and cargo volume handled for 3 years

Berth Name	Specification and Operation situation of the Terminal				
	Berth length (m)	Depth of Water (m)	Berth size (DWT)	Number of ships entered	cargo Volume handled (RT)
Berth 41	280	14	50,000	243	4,221,687
Berth 42	240	12	30,000	391	4,691,573
Berth 43	240	12	30,000	345	1,893,038
Berth 44	240	12	30,000	842	1,177,284

Berth 45	240	11	20,000	447	1,456,745
Berth 46	126	7	5,000	360	1,075,221
Berth 47	126	7	5,000	268	844,858
Berth 48	126	7	5,000	258	946,662
Berth 49	126	7	5,000	223	715,460
Berth 4A	126	7	5,000	12	30,336
Berth 4B	107	7	3,500	202	566,648

As a result of carrying the simulation in order to find out an optimal berth configuration in this study, it was found that number of total ships and total cargo volume handled are same as those of actual data but there was a change in occupancy ratio and waiting ration of the whole berths.

For finding optimal the berth configuration, we tried to select the number of berths while eliminating the berths which handles the least volume of cargo and the number of calling ships. The result of simulation test will be shown on the <Table 10>.

Considering the criteria of 60% of proper berth occupancy rate and less than 5% of permissible ship waiting ratio, the optimal alternative of berth configuration is found 8 berths consisting of a 50,000 dwt berths, three 30,000 dwt berths, three 5,000 dwt berths and a 3,500 dwt berth. If we consider lower operation cost and higher occupancy ratio, the 7 berths consisting of a 50,000 dwt berths, three 30,000 dwt berths, two 5,000 dwt berths and a 3,500 dwt berth will be selected as an alternative even if its waiting ratio and occupancy is a little higher than the former alternative.

<Table 10> Result Values of Simulation for New Berth Configurations

Simulation Result					
Number of Berths	Berth Configuration	number of ships entered	Waiting ratio (%)	Occupancy Ratio (%)	Cargo Volume Handled
10	50,000 x 1 30,000 x 3 20,000 x 1 5,000 x 4 3,500 x 1	3,576	1.5%	49.7%	16,865,693
9	50,000 x 1 30,000 x 3 5,000 x 4 3,500 x 1	3,570	1.7%	55.4%	17,401,828
8	50,000 x 1 30,000 x 3 5,000 x 3 3,500 x 1	3,583	2.1%	62.0%	17,688,794
7	50,000 x 1 30,000 x 2 5,000 x 3 3,500 x 1	3,450	51.7%	78.3%	20,995,582
7	50,000 x 1 30,000 x 3 5,000 x 2 3,500 x 1	3,596	7.9%	69.6%	19,166,586
6	50,000 x 1 30,000 x 3 5,000 x 2	3,514	44.9%	76.5%	19,116,760

7. CONCLUSION

This study intended to figure out the optimal berth configuration analysing Port-MIS data of 11 steel berths of the Gwangyang Port for 3 years. The author presents the optimal berth configuration based on UNCTAD standard through its own designed simulation premising that the optimal berth configuration is the results showing 65% of berth occupancy ratio and less than 9% of ship waiting ratio and presents the optimal berth configuration out of several berth configurations simulated earlier. The optimal berth configuration would be 7 berths configuration instead of 11 berths for handling the present cargo volume.

The optimal berth configuration consisting of a 50,000 dwt berths, three 30,000 dwt berths, three 5,000 dwt berths and a 3,500 dwt berths, total 8 berths is proposed as the optimal berth configuration for the cargo volumes of the steel terminal and it is expected to have an effect to save the operation and construction cost by establishing such optimal berth configuration.

The contribution of this study is to suggest the method for finding optimal configuration of existing berths using simulation technique without interrupting the handling capacity of current cargo volume under proper berth occupancy rate and permissible ship waiting ratio.

Acknowledgements

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