Journal of Navigation and Port Research International Edition
Vol.33, No.2 pp. 153~159, 2008 (ISSN-1598-5725)

Critical Factors for Container Terminal Productivity

Nam-Kyu Park† · *Joo-Young Kim**

† *Department of Distribution Management, Tong-Myoung University, Busan 608-711, Korea*
* *Department of Distribution Management, Tong-Myoung University, Busan 608-711, Korea*

Abstract : *The awareness of the high-value industry for container terminal leads competitiveness of container terminals to keep high fiercely. In regards to competitive factors of container terminal, the most important point among several factors is seemed to be the speed of container loading and unloading on quayside. In container terminals in Korea, the productivity shows big difference even though its condition is similar to each terminal. The objective of this paper is to find the critical factors of container terminal productivity, which is dependant upon the capability, quantity of quay crane, transfer vehicle, and so on. For this purpose, we have researched related literatures, and collected data about container terminals in South Korea. Furthermore, we tested sensitive analysis to evaluate the extent of productivity by changing independent variable. And then we established the regression model to evaluate which factor has had the biggest impact on productivity. The results of this paper can give terminal operators guideline to improve productivity.*

Key words : *Critical Factor, Container Terminal Productivity, Evaluation Modeling, Regression Analysis, GBP*

1. Introduction

The efforts to be a hub port among competitive ports have been intensified; in a result each terminal has invested lots of budgets to improve productivity. The examples for productivity improvement has been shown in different types recently, those are the lengthy arm of quay crane reaching 24 bays, high lifting capacity quay crane like twin-lift and tandem-lift, RFID technology for identifying vehicle and container in remote distance, dual cycle operation and pooling system of yard tractors for equipment productivity, the high capacity yard crane like RMGC and High Stacking System etc.

The method, which measures the productivity of the container terminal, is largely divided with the traditional productivity analytical method and data envelopment analysis. The traditional method is referred to area with the facility productivity analytical method and the synthetic method of productivity. The data envelopment analysis, which presents the combined analysis about the multiple input factors and multiple output factors, is classified in CCR models, which Charnes and Cooper and Rhodes etc. presented in 1978, and BCC models which Banker, Charnes and Cooper etc. presented in 1984. But the traditional method has difficulty in treating various variables synthetically. And DEA, which easily analyzes relative comparison between terminals, including the general factors (CCR model), has difficulty in examining the relationship of the each variable.

So, this study intended to find out relationship between productivity indicator and its factors impacting productivity, and also the factors order of impacting productivity while defining the concept of productivity in container terminals.

The factors that affect productivity of the container terminals are composed of infrastructure, superstructure, human resources and information structure, and automatic technologies.

In this study these considerable factors are discovered through the process of literature review, discussion with experts in working in container terminal for more than 20 years, and brainstorming. And these factors are classified into few categories and then tried to collect related data in container terminals in South Korea. A regression analysis is executed based on collected data. Then this study intends to find the relationship between, dependent variables which are terminal productivity, and independent variables with the element that affects them.

This study considers the container terminal productivity with unit productivity. The unit productivity means gross berth productivity (GBP), which is calculated with formula which divides annual total throughput of the terminal by total berthing time and number of berths in standard dimension. The applied data is gathered from 16 container terminals of Korea. In the process of data analysis, some data are found to be difficulty to measure, and it has been excluded from statistical analysis.

The composition of this study is as follows. First, chapter

† Corresponding author: Nam-kyu Park, nkpark@tit.ac.kr 051)629-1861
* gdhong@hanmail.net 062)320-4348

1 is introduction section: background, goal, composition and method of research. In chapter 2, productivity concept of container terminal and analytical method for productivity factors is reviewed by literature survey. In chapter 3, the model for analysis is defined and verification for model is done for model correctness. The procedure of model establishment, data acquisition and analysis are reviewed in detail level. Chapter 4 contains the result of regression analysis based on the model and data. In chapter 5, the result of research, its limitation and implication has been summarized.

2. Research Model

2.1 Establishment of Model

The goal of this study extracts the major factors which influences to container terminal productivity and define relationship with the productivity factors and productivity.

Setting up concept of container terminal productivity Generally speaking, the productivity is defined as a ratio of input and output volume of factors in production. Thus, the productivity is applied with the important judgment of the efficiency measurement.

So far, most of researches which relate to port productivity have focused on the ratio of annual handling capacity and the spent resources in the container terminal. This means productivity is depend on some aspects like marketing power, agility of business organization, the terminal area and the scale of national economy. In this point, there are a lot of rooms for considering in handling productivity problem in comparison with in handling unit facility productivity.

In the viewpoint of the efficiency which get a larger output with a smaller input, the productivity of the container terminal is defined as a volume of loading and unloading per unit time per spent resources and can be expressed with relationships which sets the volume of loading and unloading as dependent variable and the inputted resources as independent variables.

This study handles gross berth productivity (GBP) as productivity indicator. The function of the harbor converted from military affairs, fishery and the passenger service center to import and export freight center in the international trade. So, the ability for loading and unloading is most important in a port operation and it can be measured with the volume of loading and unloading per unit resource. The volume of loading and unloading per unit resource is set with annual throughput per berth i.e. with annual throughput divided by total berthing time and number of berths.

$$GBP = \frac{\sum_{d=1}^{T}(L_d + U_d)}{N\sum_{i=1}^{m} V_i} \qquad (1)$$

Where, L_d = loading volume in TEU per day,
U_d = unloading volume in TEU per day,
N = number of berth,
V_i = berthing time of each vessel,
T = working days per year,
i = number of vessel on berth

Because of the element which cannot be quantified as like business activity, it is a somewhat difficult point that annual throughput is considered as productivity indicator.

2.2 Scope of Modeling

In order to determine productivity factors in a container terminal, all factors that are relevant to terminal operation, are to be considered such as terminal facilities like yard area, number of berth, gate, and rail station, and terminal equipment like YT, QC, RTGC, RMGC, reach stacker, top handler and folk lifter and manpower.

In addition to these facilities and equipment, worker skill, the level of information technology, the extent of terminal automation and operating time is closely related to productivity. <Figure 1> simply shows related factors which affecting container terminal productivity. This figure is drawn from South Korea's main terminal in 2006, based on operational data.

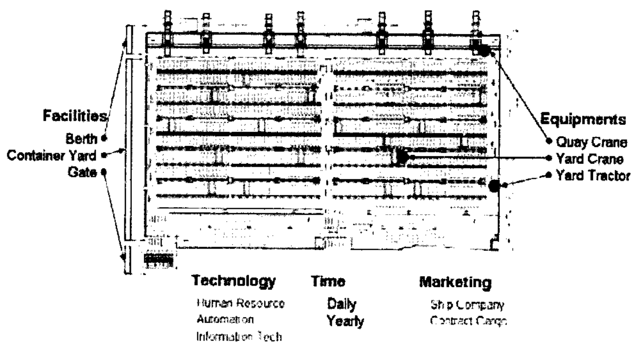

Fig. 1 Productivity factors in container terminal

2.3 Modeling Method

Independent variables are established by extracting the whole major factors which have relationship with productivity and by normalization process. For the purpose of considering the potential factors, it is necessary to do literature review, website survey, interview and brain-storming, and checking duplicated factors in context.

Normalization process consists of three steps. First the extracted elements which were in a disorder are categorized by general criteria on facility, equipment, technology, business activity and working time. Next step is to find duplicated factors in comparing the attribute context each other. If duplication in context is found, the factor is excluded from independent factors. Final step is to apply other criteria to remaining factors in order to identify if it has qualification of independent variables.

After final selection of the independent factors, interrelationship between independent variables and dependent variables can be established. After collecting data, regression analysis is done by procedure such as enter, remove, stepwise, forward and backward, with using GBP as dependent variable.

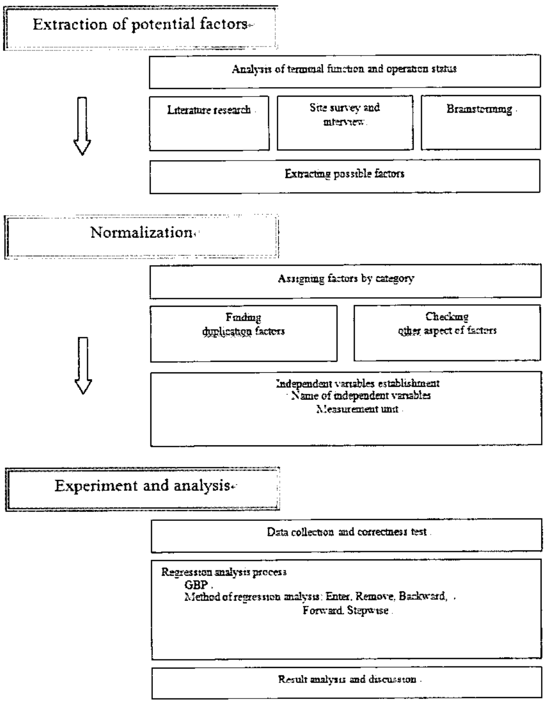

Fig. 2 Research procedure

2.4 Method of Regression Analysis

The various variable selection methods are applied on the ground of 'principle of parsimony' which removes independent variable of coherence low-end in a multiple regression model.

This study try many methods, such as Enter, Remove, Backward, Forward, Stepwise, and then Backward is selected as the best method for results.

Backward elimination method progress as follows. Firstly, estimate the model with all the predictors. If all the regression coefficients are significant, the procedure stops. Secondly, the predictor with the smallest significance in the regression coefficient test is eliminated from the model. Finally, the procedure stops, when all the regression coefficients are significant. On the one hand, forward selection method progress as follows. Firstly, the variable, which has the strongest and significant correlation, is taken into the model. Secondly, calculate the partial correlation between the variables not in the equation and the model. The variable with the strongest and significant correlation is taken into the model. Finally, the procedure continues until there is no significant partial correlation. The statistical analysis of GBP is implemented in two types because the relative difference of data between port of Busan and port of Gwangyang is remarkable.

2.5 Deciding independent variables

There are various general factors impacting terminal productivity, which can be distinguished from facility, equipment, technology, business activity and working time.

In considering facility related to factors, we can extract berth factor where vessels lie alongside, the container yard factor where containers stock, the gate factor where containers enter and leave. In considering the berth related factor in detail, we can extract the number of berth, the length of berth, and berth occupancy ratio as independent factor. However as the number of berth have duplicate characteristics with the length of berth, it can be excluded as independent factors. Furthermore berth occupancy ratio can be excluded, because it is not the input factor of productivity but a result of terminal operation.

In considering container yard related factor, the total terminal area, TGS, the height of stack, dwell time, and utilization of container yard can be extracted as major factors of productivity, yet the total area is excluded because it can be duplicated with TGS. Furthermore, the height of stack and the dwell time of container in CY, even if they are the most important factors, are also excluded because its significance is too low to be guarantee. Container yard utilization ratio is excluded because it is the result of container terminal operation rather than input factor.

Other factors such as the number of lanes at gate, automation technology at gate or on yard are to be considered. Among those factors, the difficulty to measure the level of automation technology prevents it from getting qualification as independent factors. As most of terminals have multiple lanes enough to pass trucks without delay, lane of gate is not involved as independent variables.

Let me say equipment factors as productivity indicator.

Quay crane, yard crane, and transfer equipment are most important productivity factors. Referring to equipment, two factors are to be listed. The one is how many of QC, TC, YT do each terminal own for handling operating. The other is about the lifting capability of equipment. Particularly, there are many types in QC in respect of arm's length reaching to 24 bays on container vessel, QC with twin lift which has capability to lift two 20 feet container all together, QC's height etc. Furthermore, on yard operation, RMGC shows higher productivity in handling rather than RTGC, and reach stacker, top handler, straddle carrier, folk lifter which container terminal owns shows different performance by terminal. In yard tractor operation, different performances are revealed depending on operation type like YT pooling or dual cycle. However, in this paper, I assume the same type of equipment has similar performance on average. As a result of discussion, the number of equipment is only factor to consider for productivity factor.

In referring to operation technology, big variance in performance exists depending on workers skill, the level of information technology and automation in terminal. If we analyze workers' skill in detail level, it can be divided into skill of site work like QC, YT, TC drivers, and management skill on level of operation, tactical and strategy. However, measuring workers and management skill is not only difficult to ensure objective validity, but also estimate the impact to productivity on worker efficiency.

Referring to the level of information technology, different types of technology are implemented on gate, on yard operation and on quay side. On gate, yard and quay in order to get identification of truck or container, barcode system, optical recognition system, RFID recognition system are selected according to container terminal's budget and manager preference to recognition accuracy. Referring to terminal operation system, EDI system which links to shipping company and terminal operator, terminal operation system called TOS which has control over terminal operation are implemented by all terminals. Referring to automation, unmanned yard crane used in PECT is only example in Korea even though automation in horizontal and yard handling will be implemented on southern part of Busan New Port. However, measuring the level of information and automation technology is not only difficult to ensure objective validity, but also estimate the impact to productivity on technology level.

Finally it is time to discuss business activity of Terminal Operation Company (TOC) regarding to the number of contracted shipping company and contracted amount of cargo. On high level view, even if we accept that TOC's business activity has influenced to GBP, measuring the level of business activity regarding to productivity is not only difficult to collect data owing to confidential property. Nevertheless, it is true that working hours affects productivity, but it can not be applied in this study because it has no difference by each terminal.

The above discussion will be summarized on <Table 1> reflecting context duplication characteristic and other aspect of factors.

Table 1 General factors impacting terminal productivity

Class	Source Name	Factor	Unit	Source Name	Review
Facility (A)	Berth (A1)	Berth Number (A11)	ea	4	duplication
		Berth Length (A12)	meters	4, 5	adopted
		Berth Occupancy (A13)	%	1, 2, 3	result of operation
	CY (A2)	CY Area (A21)	square meters	4, 5	duplicated
		Stack Capacity (A22)	Tier	All	insufficient significance
		Stack Height (A23)	day	All	insufficient significance
		CY Dwell Time (A24)	%	1, 3	result of operation
		Land Utilization (A25)	ea	4, 5	Assume similar performance
	Gate/ Rail (A3)	Number of lanes (A26)	ea	All	Assume similar performance
Equipment (B)	Q/C (B1)	Number (B11)	ea	All	adopted
		Capability (B12)	TEU/ hour	1, 2, 3	Assume similar performance
	T/C (B2)	Number (B21)	ea	All	adopted
		Capability (B22)	TEU/ hour	4, 5	Assume similar performance
	Y/T (B3)	Number (B31)	ea	All	adopted
		Capability (B32)	TEU/ hour	4, 5	Assume similar performance
Technology (C)	IT (C1)	High (C11)	N/A	4, 5	difficult measurement
		Medium (C12)	N/A	4, 5	difficult measurement
		Low (C13)	N/A	4, 5	difficult measurement
	Auto -matic (C2)	High (C21)	N/A	4, 5	difficult measurement
		Medium (C22)	N/A	4, 5	difficult measurement
		Low (C23)	N/A	4, 5	difficult measurement
	Human	High (C31)	N/A	4, 5	difficult measurement
Business Aactivity (D)	Contract Amount of Cargo (D1)		TEU/ Year	4, 5	difficult measurement
	Contract Amount of Cargo (D2)		TEU/ Year	4, 5	difficult measurement
Working time (E)	Working Time per Day (E1)		hours	all	difficult measurement
	Working Time per Day (E2)		days	all	difficult measurement

※ Source, 1) UNCTAD, 2) Hamburg Port Consulting, 3) Korea Maritime & Fisheries Institute, 4) Interview, 5) Papers which previously referred

2.6 Description of Data

The data applied in this study are obtained from the year of 2006. Eight terminals located in Busan, four containers in Gwangyang, three terminals in Incheon and two terminals in other area in Korea. As two terminals in Incheon and other city among target terminals just opened, they are excluded from analytical process because it does not keep normal operation. Finally, thirteen terminals data can be actually applied for analysis, which are eight in Busan, four in Gwangyang, and one in Incheon.

For making model, GBP per berth can be set as dependent variable. As we already discussed, number of berths, area of container yard, height of stack, dwell time in the independent variables are excluded owing to lower significance after regression analysis as shown <Table 1>. Finally the length of berth, twenty ground slot (TGS) of container yard, number of quay crane, yard crane and yard tractor are chosen with strong reliability as independent variables.

In summary for collected data, distribution analysis is useful to catch whole figure of target terminals resource. <Table 2> shows resource distribution of terminal both in port of Busan and port of Gwangyang by GBP.

Table 2 GBP in port of Busan and Kwangyang

Class	Busan	Kwangyang
GBP	58.8 ~ 168.6	21.8 ~ 107.2
Berth Occupancy	37% ~ 80%	16% ~ 48%
Length of berth	250 ~ 350	279 ~ 350
TGS	1119 ~ 3286	1969 ~ 3712
Gate lane	1.3 ~ 4	1 ~ 6
Q/C	3 ~ 4	1 ~ 3
T/C	7 ~19	2 ~ 9
Y/T	12 ~ 24	3 ~ 15

As shown above <Table 2>, the remarkable difference in GBP in port of Busan and port of Kwangyang is found through the result of data analysis. If data both in port of Busan and port of Gwangyang put into one basket together, the 'error of combinations' can be happened due to wide variance. Therefore the statistical analysis is implemented separately by port of Busan and port of Gwangyang.

3. Resulr of Analysis

3.1 Analysis result of port of Busan including Incheon terminal

As already discussed in section 3, independent variables are composed of number of yard tractor, TGS, number of TC, number of QC. When backward elimination method is applied to the model, the R square which means the coefficient of determination(SSR/SST) ranges from 0.931 to 0.961. These five independent factors explain model in a good fitness. In ANOVA analysis, the significant probability is p=0.26 in applying five independent variables and reaches 0.00 if the independent variable with high significant value removed orderly. If we set the level of significance 5%, the regression model is valid only when TGS as independent factor removed. However if we check significance probability on each independent variables, number of yard tractor and length of berth can be accepted as valid independent factor of which value are 0.006 and 0.028.

Table 3 Regression model summary(e)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.980(a)	.961	.895	12.04218
2	.980(b)	.960	.920	10.48764
3	.970(c)	.941	.905	11.43865
4	.965(d)	.931	.908	11.28533

a Predictors: (Constant), Yard_Tractor, TGS, Length_Berth, Yard_Crane, Quay_Crane
b Predictors: (Constant), Yard_Tractor, Length_Berth, Yard_Crane, Quay_Crane
c Predictors: (Constant), Yard_Tractor, Length_Berth, Quay_Crane
d Predictors: (Constant), Yard_Tractor, Length_Berth
e Dependent Variable: GBP

Table 4 ANOVA(e) analysis summary

Model		Sum of Squares	df	Mean Square	F	Sig
1	Regre-ssion	10580.031	5	2116.006	14.592	.026(a)
	Residual	435.042	3	145.014		
	Total	11015.074	8			
2	Regre-ssion	10575.112	4	2643.778	24.036	.005(b)
	Residual	439.962	4	109.991		
	Total	11015.074	8			
3	Regre-ssion	10360.860	3	3453.620	26.395	.002(c)
	Residual	654.214	5	130.843		
	Total	11015.074	8			
4	Regre-ssion	10250.922	2	5125.461	40.244	.000(d)
	Residual	764.152	6	127.359		
	Total	11015.074	8			

a Predictors: (Constant), Yard_Tractor, TGS, Length_Berth, Yard_Crane, Quay_Crane
b Predictors: (Constant), Yard_Tractor, Length_Berth, Yard_Crane, Quay_Crane
c Predictors: (Constant), Yard_Tractor, Length_Berth, Quay_Crane
d Predictors: (Constant), Yard_Tractor, Length_Berth
e Dependent Variable: GBP

Table 5 Coefficients(a)

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	sig
(Constant)	-155.168	53.814		-2.883	.063
Length_Berth	.423	.214	.378	1.977	.142
TGS	.002	.009	.032	.184	.866
Quay_Crane	25.157	19.414	.334	1.296	.286
Yard_Crane	-2.623	2.135	-.289	-1.229	.307
Yard_Tractor	4.833	1.748	.590	2.765	.070
(Constant)	-157.836	45.137		-3.497	.025
Length_Berth	.435	.178	.389	2.443	.071
Quay_Crane	25.610	16.772	.340	1.527	.201
Yard_Crane	-2.553	1.829	-.282	-1.396	.235
Yard_Tractor	4.856	1.519	.593	3.198	.033
(Constant)	-127.266	43.045		-2.957	.032
Length_Berth	.391	.191	.350	2.048	.096
Quay_Crane	14.916	16.272	.198	.917	.401
Yard_Tractor	4.190	1.572	.511	2.665	.045
(Constant)	-118.936	41.510		-2.865	.029
Length_Berth	.476	.165	.426	2.883	.028
Yard_Tractor	5.092	1.211	.621	4.206	.006

a Dependent Variable: GBP

The regression formulate which is composed of selected variables is shown <Formulation 2>

$$GBP = -118.936 + 0.476X_1 + 5.092X_2 \quad (2)$$

$$Where,\ X_1 = Length\ of\ Berth$$

$$X_2 = Quantities\ of\ Yard\ Tractor$$

In port of Busan, the order of importance based on standardized coefficient which affects GBP is show as <Formulation 3>

Yard Tractor > Length of Berth > Quay Crane > TGS > Yard Crane (3)

3.2 Analysis result of port of Gwangyang

When enter method is applied to the model, even though the R square is 1.0, mean square error is 0. This means any significant result can't be extracted notwithstanding applying all methods. This is caused by small number of sample, long-term storage of container in terminal.

4. Conclusion

This study aims at extracting the major factors which affect gross berth productivity (GBP) in Korean port. Furthermore the paper tries to identify the relationships between dependent variable and independent variable and the order of importance among the factors as to improve productivity in Korean container terminal.

For this purpose, we extract potential factors from literature, interview and site observation. After verifying potential factors, we made the regression model and did model test using ANOVA statistics. The experimental data is collected in scope of container terminal which opened in South Korea.

The remarkable difference between in Busan and in Gwangyang is detected through the result of the analysis. In Busan case, the factors which are directly related in loading and unloading operation such as Yard Tractor, Quay Crane, and Berth have higher inter-relation with productivity.

This suggestion means the major function of port of Busan for improving is loading and unloading.

<Table 6> summarized the results of regression analysis in making GBP with dependent variable in port of Busan and in port of Gwangyang.

Table 6 Results of regression analysis in making GBP

Port			GBP
Port of Busan	Factors in below 0.05 Sig		Yard Tractor Length of Berth
	The order of significant	1	Yard Tractor
		2	Length of Berth
		3	Quay Crane
		4	TGS
		5	Quantities of Yard Crane
Port of Busan	Factors in below 0.05 Sig		None
	The order of significant	1	—
		2	—
		3	—
		4	—
		5	—
		6	—

From a standpoint of shipping company being customer of container terminal, the company use port of Busan in expecting of speedy loading, unloading and trans-shipment.

In short, this study reveals that the improvement of GBP in Korean container terminal has closely relationship with factors such as number of quay crane, number of yard tractor and length of berth. This result is similar to the study that the productivity in Busan port which the mean length of berth is 289m is lower than foreign competitive port which the mean length of berth is 304m. The result of this study will contribute to give tips for the priority of investment for an improvement of productivity in constructing or under operation.

But this study has the many weak points. Firstly, the synergistic effect which follows in scale can be excluded because resources are divided arithmetically by number of berth in GBP. Recently, the fact is reported that the performance of crane, especially twin-lift, above 24 bay Quay Crane or automatic level affect improvement of productivity. But in this study the technology factors can not be considered due to measurement. And we have to point that there is a difficulty to generalize owing to smaller sample and restricted area.

Acknowledgement

This research was supported by Ministry of Knowledge and Economy, Republic of Korea, under the ITRC (Information Technology Research Center) support program supervised by IITA(Institute for Information Technology Advancement)" (IITA-2009-C1090-0902-0004)

References

[1] Acosta, M.(2007), "Port Competitiveness in Container Traffic from an Internal Point of View: the Experience of the Port of Algeciras Bay", MARIT.POL.MGMT, VOL. 34, NO.5, 501-520.

[2] CAI, Y.(2006), "Simulation optimization for berth allocation in container terminals", Chinese Journal of Construction Machinery.

[3] Carlos, P.(2007), "Comparing Productivity Change in Italian and Portuguese Seaports Using the Luenberger Indicator Approach", Maritime Economics & Logistics.

[4] CCDoTT(2000), "Center for the Commercial Deployment of Transportation Technologies", Port Economy.

[5] Chen. Y(2006), "Europe and Asia Standard Container Berth Production Technology Application Comparative Analysis", China Water Transport.

[6] Choi, Y.S.(2006), "A Technical Review of Container Terminal Remodeling : the Case of Busan Port ", Journal of Korean navigation and port research.

[7] GU, M.(2006), "Energetic Singapore container terminal", Port Economy.

[8] Kim, K.Y.(1999), "A Routing Algorithm for a Single Straddle Carrier to Load Export Cotainers onto a Containership", International Journal of Production Economics Vol. 59, pp. 425-433.

[9] Park, N.K.(2004), "A Simulation Model for Improving the Productivity of Container Handling in the Container Terminal", International Journal of Navigation and Port Research.

[10] Park, N.K.(2006), "Port Logistics System Using Simulation Technology", Bumhan Publsiher, Seoul, Korea.

[11] Peng, C.S.(2007), "Comparing China Container Terminal with Foreign Mega-Container Terminal Productivity", Transport market.

[12] Prabir, D.(2006), "Total Factor Productivity Growth: Indian Ports in the Era of Globalization", Maritime Economics & Logistics.

[13] Sachish, A.(1996), "Productivity functions as a managerial tool in Israeli ports", MARIT. POL. MGMT., vol. 23, No.4, 341-369.

[14] Yoo, M.J.(2003) "Evaluation of Container Terminal Types", Journal of Korean navigation and port research.

Received 25 August 2008
Revised 9 February 2009
Accepted 18 March 2009