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Port Capacity Evaluation Formula for General Cargo

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Contents

Abstract

The objective of this research is to study the evaluation method of berth capacity for general cargo in port. Specially, this study discussed the evaluation formula for general cargo berth capacity. It described the traditional evaluation method and new evaluation method with a sample case using real data of the general cargo berth. The results of the study revealed some problems for traditional evaluation method of general cargo handling capacity. Traditional calculation method does not reflect real situation for the general cargo berth capacity. Also, it does not reflect individual circumstances in terms of input parameter like berth occupancy rate, an annual working day and daily working hour. Finally, this study recommended the applicable and effective formula to reflect real situation on ports which can give direction for developing evaluation of formula for general cargo port capacity.

Key Words : Port, Capacity, General Cargo, Evaluation, Formula

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I. Introduction

Proper general cargo berth capacity is a handling capacity to cope with incoming cargoes without ship waiting for berth occupancy which leads to the port with competitive edge. There are a lot of insufficiencies to measure the port capacity due to the following factors: the sheer number of parameters involved; the lack of up-to-date, factual and reliable data which are collected in an accepted manner and available for publication or divulgation, the absence of generally agreed and acceptable definitions, the profound influence of local factors on the data obtained, and the divergent interpretations given by various interests to identical results.

The principal objective of this study is to attempt to reevaluate the formula for cargo handling capacity of general cargo berth. Under the given circumstances, it is very important to agree on a basic and common methodology. Hence, in the following section an attempt will be made to formulate generally acceptable notions before analyzing the factors determining port performance and, then, suggesting methods of comparison through a generally agreed calculation of real data. From the previous research on the measure of port performance and capacity, one fact emerges as of paramount importance: port performance and capacity cannot be determined by only one indicator or by a single all-encompassing value. The complexity of port operations, and in particular the interaction between various essential elements such as the efficiency with ships, berthing space, equipment and labor are utilized, make it compulsory to rely on a set of indicators if one wants to arrive at an accurate and meaningful evaluation of a port’s performance.

This study discussed the evaluation formula for general cargo port capacity with calculation examples using real data of the general cargo berth. Firstly, the paper reviewed the relevant literature on port capacity evaluation method and found some problems on traditional evaluation method of port capacity of general cargo. This leads to a need to make improvements on traditional evaluation method. In revising the existing method, this study recommended the innovative evaluation method of formula for general cargo handling capacity. The result, after applying new evaluation method with a sample case, revealed the different value in comparison with the value of traditional method.

II. Literature Review

1. A Study of Calculation Using Formula

1.1 UNCTAD[1)2)]

Theory on the estimation of the cargo handling capacity at ports presented based on UNCTAD which are "Berth Throughput" published in 1973 and "Port Development" published in 1985. UNCTAD suggests that the cargo handling capacity at ports is separated by a proper capacity and intrinsic capacity.

Intrinsic capacity is assumed that the system calculated as the handling capacity per hour per ship for 365 days per year, 24 hours per day. (UNCTAD, 1973) In contrast, the proper handling capacity considers the utilization ratio of handling equipment, the waiting ratio of berth, actual handling time and actual available quay working days. UNCTAD tried to calculate the cargo handling capacity of the port using a unique calculation model including several deciding factors.

Calculation method of 1985 that average capacity per QC has been reduced from 25 to 20 in 1973. Hatch opening output loss is exempted. In conclusion, handling capacity during 24 hours has been reduced by about 11.1% by 864 in 1973 to 768 in 1985.

<Table 1> Terminal handling capacity calculation of UNCTAD

	Basic assumption	Calculation method
Berth throughput (1973)	-Average capacity per QC: 25 units per hour -QC assigned per ship: 2 -Hatch opening output loss: Basic capacity 10% - Ratio of working hour for berthing time: 0.80	Handling capacity during 24 hours= 24 x (Crane average capacity/hour) x (Average G/C assigned per vessel) x (Output loss by hatch opening) x (Ratio of working hour for berthing time) = 24 x (25x2) x (0.90) x (0.80)= 864 containers
Port development (1985)	-Average capacity per QC: 20 units per hour -QC assigned per ship : 2 - Ratio of working hour for berthing time: 0.80	Handling capacity during 24 hours = 24 x (Crane average capacity/hour) x (Average G/C assigned per vessel) x (Ratio of working hour for berthing time) = 24 x (20x2) x (0.80)=768 containers

Source: Adopted form UNCTAD (1973, 1985)

1) UNCTAD(1973), pp.18-24.
2) UNCTAD(1985), pp.120-124.

1.2 World Bank

World Bank (1993) defined the study of the Port productivity index that was divided into three types: by operational productivity, assets (equipment) productivity and financial productivity indicators as shown in <Table 2>.[3)]

<Table 2> Port performance indicators of World Bank

Classification	Port Performance Indicators	Formula
Operation	Average shipping turnover	Total port time / Total number
	Ship average capacity per day	Total handling volume / (total ship number*port time)
	Average berthing time	Total berthing time / Total berthing number
	Average cost berthing time	(Total port time –total berthing time) / total call number
	Average waiting time	Total pier waiting time / waiting number
Asset	Gang per hour cargo volume	Total cargo volume / (gang*time)
	Equipment per hour cargo volume	Total cargo volume / (Working equipment number*time)
	Berth throughput	Total cargo volume / berth number
	Berth per m handling volume	Total cargo volume / berth total length (m)
	Cargo port time per ton	(Cargo volume* port time) / Handling volume
	Berth occupancy ratio(%)	Ship berth time / total ship number*365
	Berth usage ratio (%)	Handling berth time / Ship berthing time
Finance	Ship by GT income(expenditure)	Total income(expenditure) / total GT
	Handling per ton operation profit	Operation profit / total handling ton
	Gross profit margin	Operation profit / Operation income

3) World Bank(1993)

1.3 MARAD [4]

MARAD proposed the calculation method of port handling capacity focusing on United States ports in 1986. This method is divided into 9 modules by each type of cargo in the United States which is suited for each characteristic.[5]

(1) Cargo type classification

Nine (9) cargo types of Break-Bulk (a small amount of mixed cargo), Neo-Bulk (new bulk cargo), Container, Oxide cargo-silos, Oxide-cargo-silo, Oxide cargo-open storage, Liquid cargo (except oil and ship size)

(2) Three levels for evaluating terminal capacity

- MARAD defined 3 levels by situation in order to evaluate the terminal capacity. Three different classes of port situations are based on planning stage, diagnostic evaluation stage of currently operating port and expansion of the existing port.
- For measuring port capacity in port planning stage, it is required to apply similar terminal data to the port. For diagnostic evaluation of operating port and expansion of the existing port, it is required to apply actual operating data as input value.

<Table 3> Defined level for evaluating terminal capacity

Grade	Each situation	Purpose of classification
1/2	Planning stage of port development	- Understand port size and type - Understand annual throughput by port structure
2/3	Diagnostic evaluation of currently operating port	- Capacity calculation based on operating throughput - Calculation considering the feature of port facilities (berth and open storage etc.)
2/3	Expansion of the existing port	- Based on master plan of port development - Use objective evaluation data for port development

Source: Adopted from MARAD (1986)

4) U.S. Department of Transportation Maritime Administration
5) MARAD(1986)

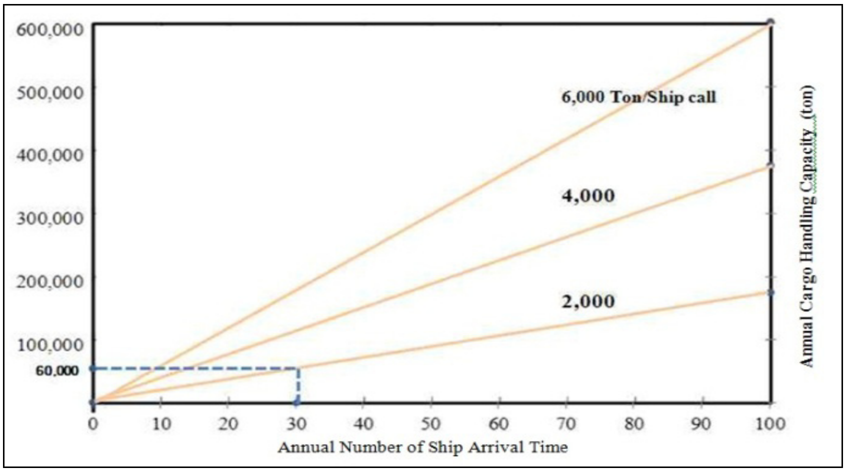
(3) Port capacity by six components

Measuring port capacity requires dividing port by 6 components in order to find bottleneck site in the detail level. Each component is composed of the vessel size and frequency, ship/apron transfer capacity, apron/warehouse capacity, yard storage capacity, yard/land transportation capacity, and gate processing capacity.

Two graphs among 6 component show how modular method can be used to estimate the cargo throughput capability of marine terminals. In the first graph, e.g. a typical ship carry 1,500 ton per call and typical number of call is 33, the throughput becomes 33 x 1,500 = 49,500 tons per year. In the second graph, let me suppose the typical value of 0.25 tons per year per sq. feet for annual throughput terminal area and the terminal has 156,000 square feet. The throughput of storage becomes 0.25 x 156,000 = 39,000 tons per year.

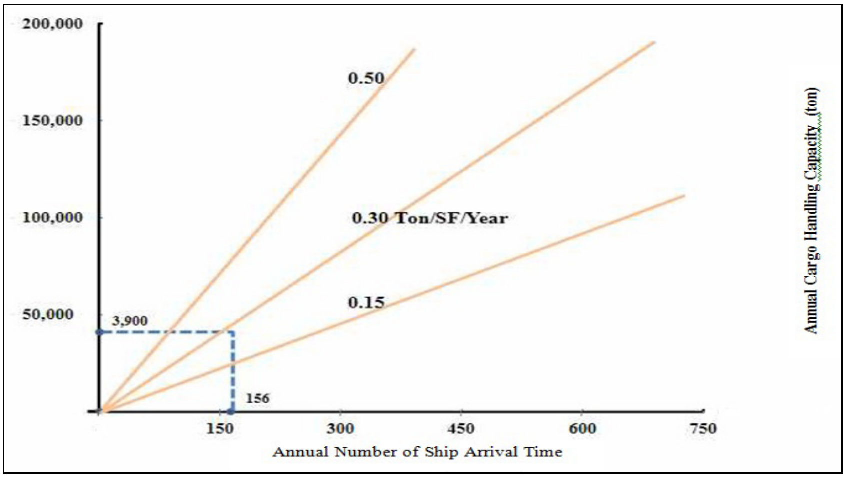
When you compare all the component estimates, you can see that the storage component is the limiting factor. Consequently, you can now estimate the annual cargo throughput capability of the terminal to be 39,000 tons per year.

<Figure 1> Ship size and frequency



Source: Adopted from MARAD (1986)

<Figure 2> Yard storage capacity



Source: Adopted from MARAD (1986)

1.4 KMI [6]

The evaluation method for general cargo proper handling capacity is divided into two types: one is the specialized berth capacity which is handling a type of item per berth and another is general cargo berth's capacity which is handling more than two items per berth. Previous research reviewed the results according to the characteristics of these cargos for specialized pier cargo types, such as: scrap metal, grain, cement, wood, steel, iron ore, coal, automobiles, sand and equipment used whether evaluation method is applied. Basically, specialization pier uses an annual handling capacity based on the equipment installed.

The specialized capacity of the terminal is calculated with the following expression.

The specialized berth handling capacity is expressed as:

$= B \times N \times C \times \sum P_i \times E \times H \times D \times O \times U$ ....(2.1)

B: Number of berth

N: Number of handling equipment

C: Hour capability of handling equipment (nominal recovery capacity x 10 turns)

$\sum P_i$: Cargo i occupancy ratio (2 or more kinds of cargo handling in the same berth)

6) KMI(1998), pp.142-167 (IV).

E: Work efficiency of handling equipment (70% usage)
H: 1 day working hours (standard 16 hours, RO/RO berth 20 hours, car 12 hours)
D: Annual number of capable working days (standard 300 days, RO/RO berth 330 days)
O: Berth occupancy rate (standard queuing rate 10%, 50% to 60% apply differential depending on the number of berth)
U: Machine utilization rate (standard 90%)

Applying the above formula to estimate specialized grain berth, berth capacity per year of 3,000ton~5,000ton berth size becomes 899,640R/T, that of 10,000ton~20,000ton berth size becomes 1,028,160R/T, and that of 30,000ton~50,000ton berth size becomes 1,259,496R/T.

<Table 4>Annual handling capacity of grain specialization pier for traditional evaluation method (example for Incheon Port)

Section	Name	3,000~ 5,000ton	10,000~ 20,000ton	30,000~ 50,000ton
N	Number of handling equipment	1	1	1
C	Hour capability of handling equipment	350ton	400ton	490ton
E	Work efficiency of handling equipment	0.7	0.7	0.7
H	1 Day Working Hours	20	20	20
D	Working days per year	340	340	340
O	Berth Occupancy Rate	0.60	0.60	0.60
U	Machine Utilization Rate	0.9	0.9	0.9
V	Annual Standard Cargo Handling Capacity	899,640	1,028,160	1,259,496

Looking into the results of port capacity evaluation by traditional method, we can find that the result does not reflect real situations as follows:

- Although the cargo volume per call has different values due to ship size, the traditional formula does not reflect such a circumstance.

- The number or size of handling equipment is dependent on the ship size; however, traditional formula does not reflect to diverse the ship size and the number of equipment

- Even though a ship occupies a specialized berth, she loads and discharges diverse kinds of cargo due to earning profit. The formula does not reflect such a situation. For example: It does not consider the proportion of scrap iron, steel, and miscellaneous cargo.

- The formula does not distinguish annual working days and 1 day working hours according to the kinds of cargo, but applied same value to different circumstance uniformly.

- The same value of nominal lifting capacity of equipment is applied, which is 10 cycles per hour without considering the characteristics of each cargo. The same value of equipment operation efficiency and machine utilization ratio was applied regardless of the different circumstance.

Therefore, by considering these limits as a formula for measuring port capacity, the authors design new evaluation method which integrates two cases of general cargo berth and specialized berth.

2. A Study of Calculation Using Simulation

The study of unloading and its calculation is trying to fully reflect the environmental or physical constraints of individual ports, docks or berths based on existing mathematical models because it has limitations and simulation calculation studies have been conducted to overcome these limitations.

In the study of Kim Chung Gon and 4 others (2001)[7)], the simulation model was used to analyze the performance of a container terminal quay which is calculated as the port of unloading and mathematical calculation model used to estimate has a conventional calculation method. To have significance and to accurately reflect the characteristics of the individual pier, these were calculated by simulation, but limited only to target quay results of simulation calculation.

7) Kim and Yang(2001)

Park Nam Gyu (2010) [8] have identified berth occupancy ratio by 50% when ship waiting ratio is 5% through simulation. As a result, calculated proper berth occupancy ratio and acceptable ship waiting ratio were reflected to quay performance and yard (or yards) to estimate the proper loading and unloading of the container terminal. This can further develop the limitation of the existing studies to consider only the quay ability. In terms of economic benefits by deriving acceptable the ship waiting ratio and proper berth occupancy ratio are of great significance to establish the important indicators for port policy.

Research at the Tong Myung University is still applied to the mathematical model to estimate that not get out the level. In the background are: 1) Handling of general cargo items number that are too diverse and complex, 2) Standardization of loading process and definition of rule are not easy when to estimate the proper productivity through simulation from the relevant port, 3) Difficulties of normalization for general cargo handling document, 4) Occurring due to many constraints from the acquisition and validation of related data.

Others, by mathematical methods to overcome the limitations of simulation studies are in progress.[9][10][11][12][13]

III. Design of New Evaluation Method

1. Improvement Points of the Traditional Evaluation Method

When we look into the results of the review and of the real analysis, the Traditional Evaluation Method cannot reflect the characteristics realistically, such as the following improvements were found:

① From the existing studies, even with the same size of berth, and according to the size of the arrival ship and items, it does not reflect the difference in the handling capacity.

8) Park(2010)
9) Dragovic, Park and Radmilovic(2005)
10) Lee, Park and Lee(2003)
11) Park, Yoon and Park(2013)
12) Park and Park(2013)
13) Esmer et al.(2010)

② Again, from the existing studies; per ship ability, it does not reflect to the distribution ratio of the actual arriving ship scale and investment of number of equipment.
③ It does not reflect to the distribution ratio of mixed cargo handling.
④ It does not distinguish annual working days and working hours per day according to the handling method but it was, instead, applied uniformly.
⑤ Machine utilization ratio was applied uniformly.
⑥ It does not reflect the variability of the number of specialized equipment. For example, specialized equipment was not used to its full advantage at the visiting place but, instead, utilized leasing methods dependent of the situation by cargo type.
⑦ There is a real case that uses a multi-purpose berth instead of the specialization pier. It does not reflect the uncertainty of whether the specialization pier is.

2. New Evaluation Method

This study suggested new evaluation method that improves the traditional general cargo handling capacity of the berth. General cargo proper handling capacity evaluation model is as follows:

$$Y = B \times \left(\sum_{i=1}^{n}\sum_{j=1}^{m} Ci \times Vj \times Tij\right) \times Dk \times Hk \times Ol \qquad (3.1)$$

Y : Proper handling capacity of the particular berth (R/T)
B : Number of berths
C_i : Cargo type ratio by each berth (%)
V_j : Vessel size ratio a berth (%)
T_{ij} : Handling capacity per hour by vessel size and by cargo type (R/T, gang capacity per hour multiplied by the number of gang)
D_k : Annual working days according to port practice. This study applies 340 days in considering weather condition of fog or storm except the public days like lunar New Year and other holiday, port operation labor union foundation anniversary day.
H_k : Working hours per day. This depends on port practice by berth and cargo type. This study applies 12 hours per day.

O_l : Occupancy ratio of the particular berth (%), (proper occupancy ratio by number of operating berths, e.g. This study applies 40% in one berth, 50% in 2 berths, 55% in 3 berths, 60% in 4 berths, 65% in 5 berths, 70% in 6 or more)
The i in the expression means a specific cargo type among 13 kinds of cargo classification, and j in the expression means a specific type of vessel size(3,000DWT~100,000DWT), k is for a handling type(mechanical, non-mechanical handling), l is for the number of operating berths.

The difference between traditional evaluation method and new method is that C_i, V_j, T_{ij} are added to the new method which reflect real situation in detail level for port capacity.

If new evaluation model is applied to real situation, the result cannot be used as standardized port capacity because of the inconsistency between the diverse scale of berths or between the several types of cargo. For example, if we estimate two berths capacity of 20,000 DWT berth and 30,000 DWT berth, the capacity of the latter is larger than that of the fore berth without question. However, the result sometimes reveals the reverse by new model. That is why we introduce the standard model in revising the original model. This study tried to normalize the parameter value of C_i, V_j , T_{ij}, D_k, H_k and O_l.

Standard C_i value : one type cargo is handled on a berth.
Standard V_j value : normalized the ship size is calling at a berth.
Standard T_{ij} value : it is used the same as original value.
Standard D_k, H_k and O_l value : the same as original value.

IV. Case Study

1. Inchoen Port in South Korea

For easy understanding of applying the new model, this paper suggests the sample case to set parameter value in the evaluation model. The data is collected from grain berth which scale is 50,000DWT in 5th port of Incheon. An annual proper handling capacity of berth 51 at Incheon port is about 1,916(RT thousand) by new evaluation model.

1,915,560 (RT) = 469.5(ton) × 340(days) × 20 (hr) × 0.6

<Table 5> New evaluation method of annual handling capacity of grain berth (Example for Incheon Port)

Section	Item	Value		Remarks
B	Number of Berth	1		
$\tilde{C}_i$	Ratio of cargo type per berth	100%		
$\tilde{V}_j$	Ratio of vessel size per berth	Less than 5,000ton	3.2%	
		Less than 10,000ton	12.9%	
		Less than 20,000ton	12.9%	
		Less than 30,000ton	12.9%	
		Less than 50,000ton	58.1%	
$\tilde{T}_{ij}$	Handling capacity per hour per ship	469.5 tons		
$\tilde{D}$	Annual working days	340 days		
$\tilde{H}$	1 day working hours	20 hr		
$\tilde{O}$	Berth occupancy rate	60 %		Standard rate
Y	Annual proper handling capacity	1,915,560 (RT)		

2. Comparison of General Cargo Ports Capacity by Traditional Method and New Method

In this section, the study analyzed the general cargo port capacity of general berth and specialization pier using traditional evaluation method and new evaluation method.

Comparing the evaluation model, this study surveyed five ports: Incheon, Mokpo, Busan, Ulsan and Gunsan ports, which handles grain cargo even though the scale of the berths is different.

The result of traditional method shows difference of throughput of same scale of berth in Incheon, Busan and Ulsan ports. The average capacity of 50,000 DWT berth is 1,492.0 and RMSE[14] is 555.5 by the fore part method. The latter part method shows average 1,613 and RMSE is 275.7. RMSE of 50,000DWT reduced from 555.5 to 275.7. This tells us that the capacity throughput by new method is accurate than that of the latter one.

Specially, when applying the fore part method, Ulsan's capacity is 127%(= (2,268-998)/998 × 100%) more than that of Incheon port even though they have same scale of berths. In comparison, the latter part shows only -13%(= (1,674-1,916)/1,916 × 100%) difference between Incheon and Ulsan.

If we apply this procedure to 20,000 DWT scale berth in Gunsan and Mokpo, the result shows same pattern as that of 50,000 DWT scale berths.

<Table 6> The comparison between traditional method and new evaluation method for specialization pier of Grain berth handling capacity

Port Name (Specialization pier)	Berth Name	Depth of Water (m)	Length of Berth (m)	Class of Vessel Size (DWT)	Proper berth capacity		Different value
					Traditional Method (A)	New Evaluation Method(B)	Specialization pier (B-A)
Incheon	No 5	5	280	50,000	998.0	1,916.0	918 (+92.0%)
Busan	No. 5	13	371	50,000	1,210.0	1,249.0	39 (+3.2%)
Ulsan	Grain	13	185	50,000	2,268.0	1,674.0	-594 (-26.2%)
Average					1,492.0	1,613.0	121.0 (+8.1%)
RSME					555.5	275.7	-279.8 (-50.4%)
Gunsan	No. 6	13	210	20,000	1,331.0	1,238.0	-93 (-7.0%)
Mokpo	Daebul. 3	12	210	20,000	601.0	870.0	269 (+44.8%)
Average					966.0	1,054.0	+88 (+9.1%)
RMSE					516.1	184.0	-332.1 (-64.3%)

For this reason, the new evaluation method is the more applicable and

14) RMSE : Root Mean Square Error, RMSE; a lower value is a good accuracy.

effective formula to affect real situation on ports and necessary to apply on reevaluation formula for general cargo port capacity.

V. Conclusion

This study discussed the present status of the general cargo handling capacity for cargo operation. It described the evaluation method of general cargo handling capacity for port capacity with examples which presently uses traditional method. As a result, this study found some problem on evaluation of general cargo handling capacity. There are improvements found in traditional evaluation method that is applied uniformly to all berths. For example, traditional method does not distinguish annual working days and per day working hours according to the handling method. Also, it does not reflect the distribution ratio of the actual arriving ship scale and the number of equipment. Furthermore, it does not reflect the distribution ratio of mixed cargo handling, for example, proportions of scrap iron, steel, and others are not considered.

But new evaluation method reflects real circumstance of ship size, and the ratio of cargo type handled on a berth. Finally, this study suggested recommendation which can give direction for developing reevaluation of general cargo handling capacity for port capacity.

By comparing traditional evaluation method and suggested method, the new evaluation method adopted new parameters of C_i, V_j, and T_{ij} which reflect in detail the port capacity. C_i is an item ratio by each berth (%, cargo handling ratio of specific berth), V_j is a size ratio by each berth (%, ship size of the specific berth ratio) and T_{ij} is a handling capacity per hour by vessel size and item (R/T, gang per hour capacity and number of gang by vessel size, item) in order to calculate in detail and reflect real situation for the general cargo berth capacity and effective movement. This expression described “*i*” for a specific cargo type (13 species of cargo classification, reflect the additional items and feature of each berth), “*j*” for a specific type of vessel size (3,000DWT~100,000DWT), “*k*” for a handling type (mechanical, non-mechanical handling), and “*l*” for the number of operating berths. This study analyzed the proper annual handling capacity using two formulas of evaluation for general cargo berth capacity. After conducting the comparison between traditional method and new evaluation method, there is a different value of annual handling capacity. This means that the accuracy of the new RMSE model was improved by each contraction from 50,000DWT and 20,000DWT than previous model RMSE.

For this reason, the new evaluation method is the more applicable and effective formula to affect real situation including each berth, item, vessel size and annual working day on ports. Hence, it is necessary to apply on a re-evaluation of formula for general cargo port capacity.

There are limitations to reflect realistically this situation in each country or ports in spite of many harbors applied this kind of formula in handling capacity calculation method of general cargo. Therefore, previous attempts have arisen to apply simulation technique by new calculation method a long time ago.

According to this formula, to overcome the limitations of the calculation method, the meaning of real situations and precise application of simulation techniques should be reflected so that there will be a worthy challenge to future studies.*

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