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A Study on the Comparison of the Capacity of Waiting Anchorage Design according to the Port Operation Method - Focusing on Busan New Port -

Jun-mo Park* · Hyoung-Seon Yang**†
*, ** Division of Navigation Science, Mokpo National Maritime University, Mokpo 58628, Republic of Korea

Abstract : *This study was conducted to propose an effective port operation method in terms of the design capacity of waiting anchorage by comparing the ratio and the number of waiting anchorage according to the port operation method of Busan New Port. For this, the Arena simulation program compared the rates of waiting vessels according to the application of the multi-user terminal, liner terminal and hybrid liner terminal operation methods. As a result, analysis suggested the necessary anchorage space can be reduced to about 18 % when using the multi-user terminal operation method and about 15.6 % when using the hybrid liner terminal operation method, as compared with the liner terminal operation method. Specifically, it was effective to apply the multi-user terminal operation method in terms of the anchorage capacity to be designated to Busan New Port. This study can apply to the designation of the new anchorage in the Busan New Port by reflecting the contents of the design of the anchorage in accordance with the port operation method.*

Key Words : *Busan New Port, Anchorage, Port Operation Method, Arena Simulation program, Necessary Anchorage Space*

1. Introduction

In Busan New Port, waiting vessels have increased rapidly due to the increased operation inefficiency, as well as the increase in the quantity of goods transported. In particular, the number of ships on demurrage and waiting numbered only 21 in 2012, but the annual average in 2016 rose by 87 % to 257 ships. As a result, waiting vessels entering Busan New Port are awaiting by anchoring in the right side of the water area of the Port of Okpo (Kwon, 2018) due to the anchorage shortage. This is because of the development in the port area or the expanding capacity of the water facility carried out due to the increasing quantity of goods being transported. As a result, the port cannot be set as the berthing area as there is high vessel traffic congestion or problems in VTS control (Usui and Inoue, 1999). It could be said that the possibility of marine casualties has increased due to the combination of the navigating vessels and vessels temporarily waiting near Busan New Port.

Therefore, the Ministry of Ocean and Fisheries and Busan Port Authority have prepared various policies to solve the problem of the waiting vessels in Busan New Port (Kim et al., 2017). Especially, as they have concentrated efforts to reduce the waiting rate of vessels by maximizing the facility utilization rate of Busan New Port by changing the liner terminal operation method to the multi-user terminal operation method. However, despite the efforts of the competent authorities, the policy has not been pursued due to the intricate interests between the berth operator and the shipping company.

In maritime traffic, anchorage is necessary for vessels to wait safely and for the smooth operation of the harbor. Measures need to be taken if the anchorage is insufficient, such as designating additional anchorage according to the harbor's situation or by reducing the rate of the vessels utilizing the anchorage. Therefore, it is necessary to examine the effective operation of the port operation method in terms of the size of the anchorage design by comparing and analyzing the number and the ratio of the waiting vessels according Busan New Port's port operation method.

A similar study on the port operation method in the harbor showed that most of the studies focused on improving the efficiency of harbors. The study of Kim et al. (2017) suggested the necessity of introducing a hybrid liner terminal system to Busan New Port, Choi's study (2005) evaluated productivity

* First Author : jmpark@mmu.ac.kr, 061-240-7180
† Corresponding Author : epicyang@mmu.ac.kr, 061-240-7178

improvement by improving the operating system of the container terminal, and Park et al. (2007) analyzed the efficiency of container terminals. In addition, Park (2010) studied the effect on the pier of the container terminal and the sharing of the facility and so on. However, it is difficult to find a case study comparing the port operation method in the harbor focusing on the waiting anchorage.

In this study, a numerical simulation technique is used to compare the rates of waiting vessels according to application of the multi-user terminal, liner terminal and hybrid liner terminal operation methods. Based on these results, we proposed necessary anchorage design capacity according to the port operation method from the viewpoint of the waiting anchorage.

2. Concept Definition and Research Methodology

2.1 Concept Definition of Port Operation Method

The port operation method according to the type of port usage can be classified into multi-user terminal, liner terminal, and hybrid liner terminal operation methods.

1) Multi-user Terminal Operation Method

The multi-user terminal operation method is a joint use of one terminal by several ship fleets. This method is in common use by various ships for terminals with three or more berths.

2) Liner Terminal Operation Method

The liner terminal operation method is also called “self terminal operation method” and refers to the port operation method that a specific shipping company develops and uses a terminal independently. Compared to multi-user terminal operation method, liner terminals are limited to a number of shipping companies, and even in the number of service routes. In addition, on-time service by vessels is strictly maintained rather than the multi-user terminal operation method. This method is the port operation method of Busan New Port.

3) Hybrid Liner Terminal Operation Method

The concept of the hybrid liner terminal operation method proposed by Stenvert and Penfold (2007) means that the operating shipping company of the pier remains intact as do the integrated management of terminal facilities, such as piers held by individual terminals.

2.2 Research Methodology

In this study, a simulation model is designed to model the port entry/departure and loading/unloading system area of the port, and to easily find the required anchorage size for each port operation method using simulation software. The simulation model construction was made using Rockwell's ARENA Simulation (Ver. 15.1).

The port of study was selected as Busan New Port consisting of container terminals and multi-purpose pier. We compared the required size of the waiting anchorage by the port operation method for five container terminals currently operating in the harbor. In addition, for the purpose of analyzing the appropriateness of the anchorage size of Busan New Port, we also included the ships in and out of the multi-purpose pier in the simulation design.

The scope of the study was limited to the general traffic flow patterns of the harbor, such as vessel arrival, anchorage waiting, vessels arriving or departing sooner to or from the shore, and the cargo handling process. Here, the unloading process refers to the process in which a ship stays for a certain period of time to unload after berthing and then departs when finishes. The reason for limiting the scope of the research to the unloading process is that in order to proceed with the connection between the storage terminal and the gate process, the procedure and object of the simulation are complicated and it is difficult to verify the simulation model and the results (Park, 2016).

3. Analysis of Busan New Port Status

In this study, we analyzed the data required for the numerical simulation implementation such as inter arrival time, tonnage ratio of incoming ships, and distribution of working hours by examining the layout of the pier, port operating status, capacity of incoming ships (Tonnage, number of ships), and anchorage status of Busan New Port.

3.1 Harbour Berth Configuration

Busan New Port is currently separated into five container terminals (No. 1 pier ~ No. 5 pier) and one multi-purpose pier. The berth arrangement of Busan New Port is as shown in Fig. 1.

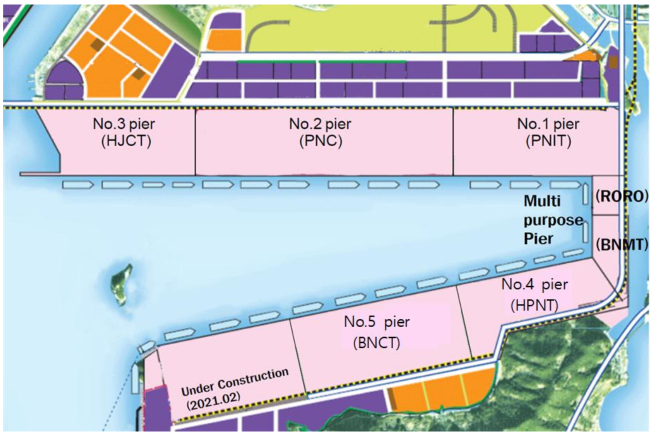

Fig. 1. Berth arrangement and terminal operation company status.

As shown in the picture above, the Busan New Port container terminal is separated into five piers and each is operated by different corporations. Each liner terminal corporation is either contracted individually to a major alliance or operated by a large shipping company. Specifically, as shown in Table 1, they are used exclusively by '2M' for No. 1 and 3 piers, 'The Alliance' for No. 2 pier, 'Hyundai Merchant Line' for No. 4, and No. 5 for 'OCEAN' Alliance and 'APL' shipping companies.

Busan New Port multi-purpose pier handled various cargo, such as containers, cars and bulk cargoes. However, 400 m of the pier was converted to container terminals in March 2018 and Busan Port Authority is operating by itself in order to secure a stable shipping company for small and medium-sized national shipping companies, and now it is used as the liner-ship pier for medium-sized national shipping. Also, pier bridges are used as car loading and unloading piers.

Table 1. Pier operation status of Busan New Port

Pier	Operating company	Exclusive use alliance or shipping company	Pier length	Depth
No.1	PNIT	2M	1,200 m	16 m
No.2	PNC	THE Alliance	2,000 m	16 m
No.3	HJNC	2M	1,100 m	18 m
No.4	HPNT	HMM	1,150 m	16 m
No.5	BNCT	OCEAN, APL	1,400 m	17 m
Multi-purpose pier	BNCT	Small and medium-ship sized national company	400 m	15 m
Pier bridge	BMNT	-	300 m	15 m

3.2 Anchorage Analysis

As shown in Table 2 and Fig. 2, Busan New Port was designated as a notification of Busan Regional Maritime Affairs and Fisheries Agency in 2008. Busan New Port's anchorage is the size of eight anchored ships at the same time, including two ships of 80,000 DWT and six ships of 60,000 DWT. The anchorage depth is 18～23 meters for W anchorage, and 15～22 meters for U anchorage.

Table 2. Anchorage status of Busan New Port

Anchorage	Capacity (DWT)	Depth (m)	Radius (m)
W-1	80,000 × 1	18～22	475
W-2	80,000 × 1	18～23	475
U-1	30,000 × 1	17～22	375
U-2	30,000 × 1	18～21	375
U-3	30,000 × 1	18～21	375
U-4	30,000 × 1	15～17	375
U-5	30,000 × 1	15～18	375
U-6	30,000 × 1	15～18	375

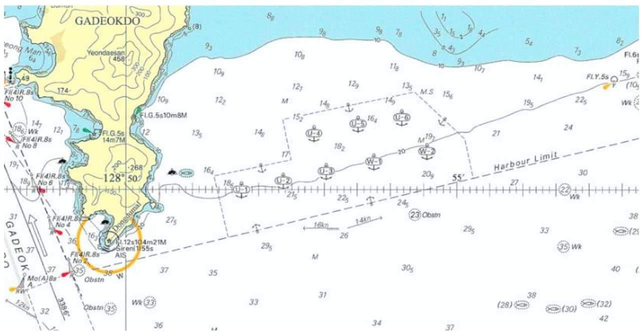

Fig. 2. Busan New Port anchorage status.

3.3 Incoming Ships Survey of Busan New Port

The container terminal of Busan New Port uses the liner terminal operation method, so vessels that can enter the berth have already been set. Therefore, the vessels entering each pier of Busan New Port were surveyed using Port-Mis system. The survey period was set from April 1, 2018 to March 31, 2019 (one year), which is the month after Busan New Port Multi-purpose pier changed to a medium-small container terminal.

1) Incoming Ships Survey

Table 3 shows the survey results of the incoming ships (Piers and anchorage) of Busan New Port for one year using Port-Mis data.

Table 3. The number of incoming ships and ratio

Pier or Anchorage		Incoming ships	Ratio
Pier	No.1 Pier	911	12.0 %
	No.2 Pier	2,138	28.2 %
	No.3 Pier	1,244	16.4 %
	No.4 Pier	1,237	16.4 %
	No.5 Pier	962	12.7 %
	Multi-purpose	893	11.8 %
	Pier bridge	185	2.5 %
Anchorage	U Anchorage	261	90.3 %
	W Anchorage	28	9.7 %

The port where the largest number of vessels enters the pier is the No. 2 pier (28.2 %), and the smallest port is the Pier Bridge (2.4 %). And the anchorage has the highest use rate of U anchorage.

2) Analysis of Incoming Ship's Tonnage Ratio

Fig. 3 is the incoming ship's tonnage ratio of Busan New Port.

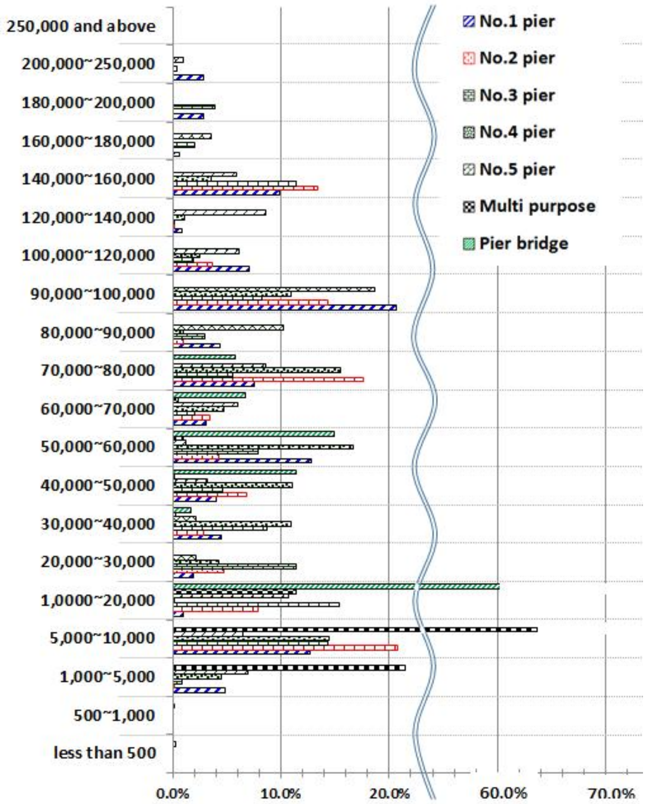

Fig. 3. Incoming ship's tonnage ratio by port.

It was surveyed that big container ships from 50,000-ton class to 160,000-ton class vessels arrived at No. 1 ~ No. 5 pier of Busan New Port. In particular, No. 1 pier has the highest entrance rate of over 200,000 tons of super large container ships compared to other piers. In addition, it was surveyed that vessels with a size of 1,000 tons to 10,000 tons mainly enter the Busan New Port multi-purpose pier, and vessels with a size of 10,000 tons to 20,000 tons mainly enter the pier bridge.

3) Analysis of Working Hours

Fig. 4 represents the working hours of each pier.

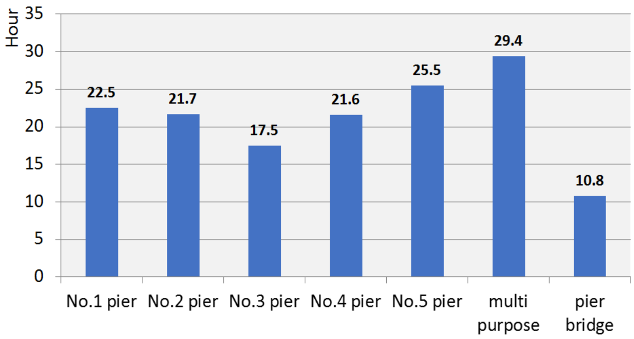

Fig. 4. Analysis of working hours of each pier.

As a result of analysis, the working hours of No. 3 pier is 17.5 hours, which is the shortest when compared with other piers except the pier bridge. The Busan New Port multi-purpose pier used by national medium-small sized container ships has the longest working time (29.4 hours). The reason for this result is that the loading equipment and auxiliary facilities of Busan New Port multi-purpose pier are relatively poor compared to container ship-dedicated piers.

4. Simulation and Analysis of Results

4.1 Model Design and Data Standardization

1) Model Design

For model design, all the processes in the harbor during the process of port entry/departure should be considered. But, in this study, the model was designed only for the pier. Gates and others are excluded from the study considering the harbor and cargo, and also the complexity of the network between vessels (Park and Park, 2013). Input and output variables are defined as Table 4.

Since the loading time of the ship among the input variables is different according to the size of the ship and the amount of cargo, the cargo-handling time cannot be set in proportion to the size of the ship entering the port. It is also difficult to estimate the amount of cargo loaded on a ship. Therefore, in this study, the working time of vessels entering the piers is investigated and standardized as probability distribution, so that realistic pier environment can be implemented.

In output variables, in order to compare the size of the anchorage design according to simulation modeling verification and port operation method in harbor, a simulation model was designed to output the vessels entering the port of each pier, number of vessels waiting, and waiting time at the anchorage.

Table 4. Input and output variables

Items	Variables
Input variables	Distribution of inter arrival time
	Pier length and number of pier
	Distribution of working hours
	Incoming ships ratio each pier
	Incoming ships tonnage ratio each pier
	Depth of fairway and berthing basin
Output variables	Amount of incoming ship
	Working hours each pier
	Amount of anchoring ship
	Waiting time at anchorage

2) Data Standardization

In order to model with the ARENA simulation program, it is necessary to standardize the variables that should be inputted in the form of distribution functions, that is, processes must be processed so as to be input to the program. Table 5 shows the results of the standardization of four variables. Here, the input analyzer tool of ARENA software was used to derive the distribution function.

We analyzed the distribution of functions between time of arrival and time of unloading work for each of the seven piers. In addition, for the simulation of the multi-user terminal operation method, it has also derived the function distribution of the time interval between the arrival of all vessels entering Busan New Port. The discrete probability distribution is applied to the ratio of inbound vessels and tonnage ratio of the inbound vessels in each pier.

Table 5. Standardization of distribution formula

Items		Distribution formula
Distribution of inter arrival time	No.1 pier	-0.001+77*BETA (1.10, 7.85)
	No.2 pier	-0.001+EXPO (4.10)
	No.3 pier	-0.001+73*BETA (0.996, 9.34)
	No.4 pier	-0.001+60*BETA (1.18, 8.79)
	No.5 pier	-0.001+76*BETA (1.14, 8.29)
	Multi-purpose	-0.001+EXPO (10.0)
	Pier bridge	2+210*BETA (0.873, 3.18)
	Busan new port	-0.001+EXPO (1.17)
Distribution of working hours	No.1 pier	5+GAMM (7.04, 2.48)
	No.2 pier	2+LOGN (19.2, 12.4)
	No.3 pier	2+GAMM (5.97, 2.59)
	No.4 pier	4+LOGN (18.2, 16.3)
	No.5 pier	5+LOGN (20.1, 15.5)
	Multi-purpose	NORM (25.3, 15.1)
	Pier bridge	0.999+LOGN (12.1, 24.4)
Incoming ships ratio each pier		Discrete Probability
Incoming ships tonnage ratio each pier		Discrete Probability

4.2 Simulation Process Design by the Port Operation Method

The simulation process is divided into the three port operation methods presented in Section 2.1, and the contents are as follows.

1) Process Design for the Multi-user Terminal Operation Method

The process design for multi-user terminal operation method is shown in Fig. 5.

Process modeling starts with creating a ship, then, if the vessel is capable of entering No. 1～No. 5 piers or the multi-purpose pier, and the piers are assigned randomly to enter the vessel. Otherwise, the vessel is designed to wait at the anchorage.

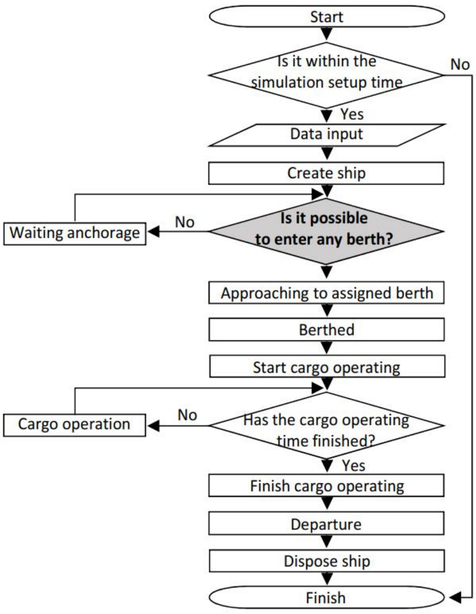

Fig. 5. Process design of multi-user terminal operation method.

2) Process Design for the Liner Terminal Operation Method

The process design for the liner terminal operation method is shown in Fig. 6.

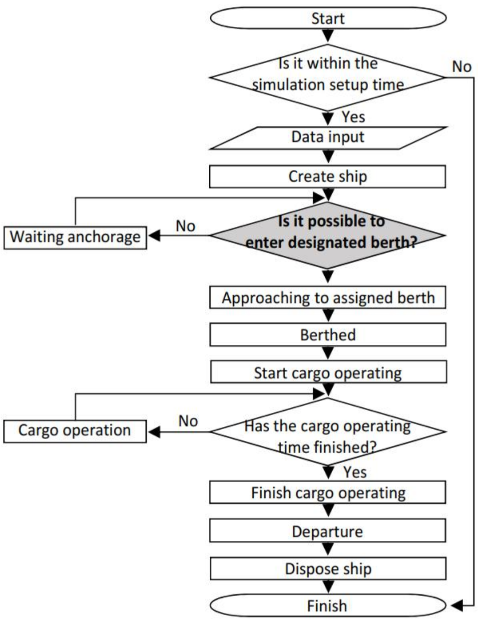

Fig. 6. Process design of liner terminal operation method.

Process modeling starts with creating a ship, then, if the vessel is capable of entering the designated pier, and the piers are assigned to enter the vessel. Otherwise, the vessel is designed to wait at the anchorage.

3) Process Design for the Hybrid Liner Terminal Operation Method

The process designed for the simulation of the hybrid liner terminal operation method is as shown in Fig. 7. After the container ship is constructed and if a pier available for entry into a liner terminal is secured, the ship shall be assigned to enter the port. However, if the pier is not secured at the liner terminal, it is designed to move to the multi-user terminal and practise the unloading work. The allocation of the pier is assigned randomly to one of the piers of Busan New Port, and without taking into consideration the inefficiency of pier operation (Within 1 km) (Kim et al. (2017)) to enter the port. It is designed to wait at the anchorage when both the liner and the multi-user terminals cannot perform the unloading work.

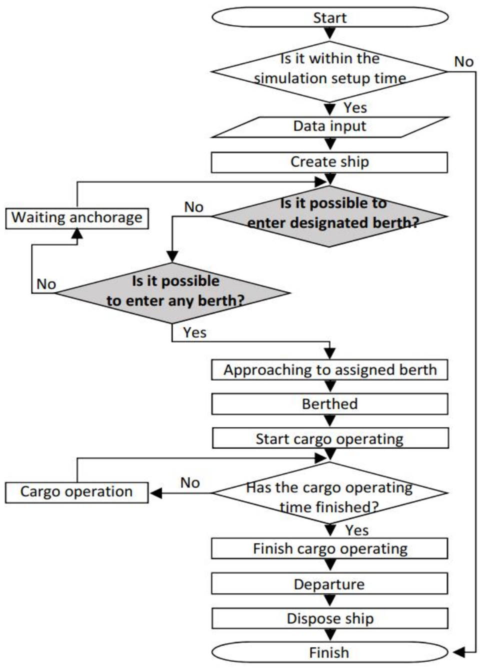

Fig. 7. Process design of hybrid liner terminal operation method.

4.3 Verification of Simulation Modeling

The simulation is performed to verify the modeling presented in section 4.2, and the results are shown in Table 6.

Table 6. Verification result of simulation modeling

Items	Operating status	Simulation result	Accuracy ratio (%)
Small ship anchorage	261	273	95.6
Big ship anchorage	28	29	96.6
Incoming ships	7,570	7,531	99.5

The simulations designed in this study cannot show the same results as real situations because the input variables are generated by each distribution (Park, 2015). However, the simulation results are valid because the analysis of the accuracy ratio of anchoring ships and the amount of incoming ships reflects reality within ± 5 % of the error range.

4.4 Simulation and Results Analysis

The simulations were repeated 20 times for each terminal operation method, and the results are shown in Table 7 and Fig. 8 ~ 10.

Table 7. Simulation result and analysis

Terminal operation method	Incoming ships	Anchoring ships
Liner terminal operation method	7,531	302
Multi-user terminal operation method	7,553	82
Hybrid liner terminal operation method	7,590	94

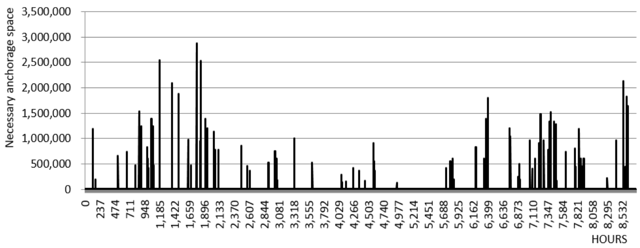

Fig. 8. Necessary anchorage space of liner terminal operation method.

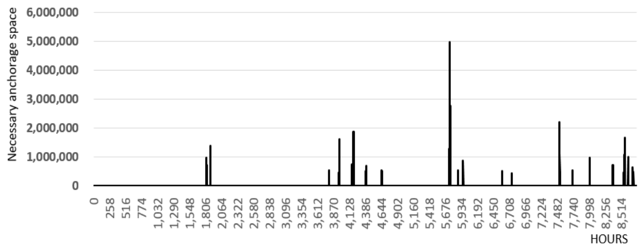

Fig. 9. Necessary anchorage space of multi-user terminal operation method.

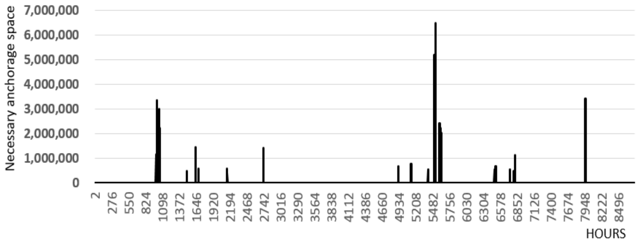

Fig. 10. Necessary anchorage space of hybrid liner terminal operation method.

As a result of the simulation, as shown in Table 7, a total of 302 anchoring vessels participated in the liner terminal operation method of Busan New Port. 82 anchoring vessels were generated by the multi-user terminal operation method, and 94 anchoring vessels were operated by the hybrid liner terminal operation method.

4.5 Comparison of Berth Design Capacity by the Terminal Operation Method

In order to determine the required anchorage capacity according to the port operation method, we examined the case of other transportation facilities to determine the size of the facility. As a result, roads and airport facilities are designed based on the 30th largest volume of traffic per year (ICAO, 2006). Therefore, in this study, it is necessary to apply the above criteria and analyze the required anchorage capacity as shown in Table 8.

Table 8. Simulation result and analysis

Terminal operation method	Necessary anchorage space
Liner terminal operation method	1,383,349.0 m^2
Multi-user terminal operation method	1,134,218.0 m^2
Hybrid terminal operation method	1,167,006.0 m^2

As a result of the study, waiting vessels at the anchorage occupy about 1,383,349m^2 in the liner terminal operation method, which is the current port operation method of Busan New Port. When the multi-user terminal operation method is applied to Busan New Port, it will be occupied at about 1,134,218 m^2. When the hybrid liner terminal operation method is applied to Busan New Port, it will be occupied at about 1,167,006 m^2.

Specifically, he anchorage capacity can be designed as small as about 18 % when using the multi-user terminal operation method and about 15.6 % when using the hybrid liner terminal operation method as compared with the liner terminal operation method. As a result, it was effective to apply the multi-user terminal operation method in terms of the anchorage capacity to be designated to Busan New Port.

5. Conclusion

This study was conducted to propose an effective port operation method in terms of the design capacity of waiting anchorage by comparing the ratio and the number of waiting anchorage according to the port operation method of Busan New Port.

In this study, a numerical simulation technique is used to compare the rates of waiting vessels according to application of the multi-user terminal, the liner terminal and hybrid liner terminal operation methods. Based on these results, we proposed the necessary anchorage design capacity according to the port operation method from the viewpoint of the waiting anchorage.

The results of this study can be applied to the designation of the new anchorage in the Busan New Port by reflecting the contents of the design of the anchorage in accordance with the port operation method.

As a follow-up study, it is necessary to apply the analysis to the port of Gwangyang and Incheon New Ports as well as the Busan New Port.

References

[1] Choi, Y. S. and T. Y. Ha(2005), An Evaluation of Productivity Improvement for Container Terminal by Introducing Operating System, Journal of Korean Navigation and Port Research, Vol. 29, No. 1, pp. 97-104.

[2] ICAO(2006), Manual on Air Traffic Forecasting, International Civil Aviation Organization, Vol. 03, No. 2016.

[3] Kim, G. S., J. D. Park, J. S. Cho and B. K. Kim(2017), Hybrid Liner Terminal Innovative Terminal Operation Concept for Busan New Port, Korea Maritime Institute, pp. 13-16.

[4] Kwon, S. C.(2018), A Study on Waiting Anchorage in Masan VTS Control Area Using Anchorage Capacity Index, Korea Maritime and Ocean University Press, pp. 73-76.

[5] Park, B. K., M. S. Choi, J. Y. Song and D. K. Ryoo(2007), A Study on the Efficiency Analysis of Korean Container Terminal, Journal of Korean Navigation and Port Research, Vol. 31, No. 1, pp. 89-97.

[6] Park, Y. M.(2010), A Study on the Effects of Sharing Berths and Cranes in Container Terminals with Different Operators, Journal of Economy and Business, Vol. 5, No. 2, pp. 121-136.

[7] Park, S. K. and N. K. Park(2013), A Study on the Estimation Model of the Proper Cargo Handling Capacity based on Simulation in Port - Port Cargo Exclusive Pier Example, Journal of the Korea Institute of Information and Communication Engineering, Vol. 17, No. 10, pp. 2,454-2,460.

[8] Park, N. K.(2015), A Study on the Waiting Cost Empirical Analysis using a Simulation, Tongmyong University Press, p. 28.

[9] Park, S. K.(2016), A Study on the Optimal Service Level of Exclusive Container Terminals, Journal of Korea Port Economic Association, Vol. 32, No. 2, pp. 137-156.

[10] Stenvert, R. and A. Penfold(2007), Container Port Strategy Emerging Issues, Ocean Shipping Consultant, p. 125.

[11] Usui, H. and K. Inoue(1999), A Method to Estimate Available Number of Anchorage, Japan Institute of Navigation, pp. 151-160.

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