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The Analysis of Ship Waiting in Oil Terminal By Simulation: The Case of Gwangyang Port

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시뮬레이션을 활용한 유류부두의 체선 완화에 관한 연구: 광양항을 대상으로

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Abstract

The port of Gwangyang, specialized in handling, has a higher ship waiting cost than other ports. This study is to research the cause of the ship waiting ratio of the dedicated oil terminal, to model ways to improve it, and to find a way to reduce the waiting time of the ship by using a simulation technique. According to the survey of Stevedore and Shipping Company, ships waiting during anchorage are caused by the problems of the berthing facility, the operational skill of cargo handling and the cargo handling facilities, such as the loading arm. We set two scenarios which are the most important reasons for ship waiting. The 1st one is to improve pump capacity to a minium of 162 MT per hour in order to shorten the berthing time. The 2nd one is to limit hose connection time to within 2 hours based on the 1st scenario. As a result of the improvement of pump capacity, average ship waiting time is reduced to 2.3 hours from current 28.1 hours, average ship waiting ratio is reduced to 18.9 % from the current 165.9 %, and berth occupancy ratio is reduced to 66.5 % from the current 85.7 %. With limits to hose connection time and improvements in pump capacity, average ship waiting time is reduced to 1.98 hours instead of the current 28.1 hours, average ship waiting ratio is reduced to 15.0 %, berth occupancy will be reduced to 64.8 % and the calling ships increase to 1,414.

Key words: Ship waiting ratio, Oil terminal, Pump capacity, Berth occupancy Ratio simulation of oil terminal

Ⅰ. Introduction

The oil port has a high ship waiting ratio[1)] due to the characteristics of oil handling with dedicated handling equipment. Especially the shipping company calling at Gwangyang port in Korea has to pay a high demurrage cost due to its high ship waiting rate. From the National Assembly audit report (2017.9) to Port Authority in 2016, the Gwangyang Port recorded a 5.2% ship waiting ratio, as a result, the loss of Gwangyang Port is

1) The waiting time of ship is divided by the ship service time. (Patrick M. A. 2008)

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reported 38.9 million USD over 3years. The purpose of this study is to identify the causes of ship waiting at Gwangyang port and suggest strategies to improve them.

The ship and cargo waiting ratios at anchorage are one of the criteria for determining how many berths develop and the level of operational efficiency and the service level for a shipping company.

A few researches have carried out about ship waiting ratio since the 1970s. Goss and Mann (1977) proposed the long-term opportunity cost is defined as the congestion cost of the ship waiting. Beth(1985) insisted that ship waiting, which is the cause of port congestion, should be understood from the view point of ship's owner or shipper. Chang and Kim (1993) estimated the daily time cost by ship size can be measured under assumption that the ship's port stay cost has exponential function.

Park et al. (2009) insisted that the waiting cost per ship, waiting time and port waiting costs is an important indicator for port users to measure port service level. Sa and Cho (2009) have studied about the cause of ship waiting of the bulker and proposed the efficient management plan for solving ship waiting of bulker.

Sa and Choi (2009) conducted hypothesis test to determine the five factors such as ship loading capacity, port characteristics, location, time of arrival and cargo throughput per ship in affecting factors of bulk ship waiting of cargo ship.

Lee et al (2015) selected ship waiting ratio and berth occupancy ratio of port as service level of port. Kim and Kim (2016) insisted that the Port Performance Indicator(PPI) of ship waiting ratio is important factor of the decision of port selection by shipowner and shipper who are port customers. In the summary, the above papers deal with the ship waiting ratio, the ship waiting time and cost are important factors to measure the port service level.

Ⅱ. The Survey of Terminal Users and Data Analysis

1. The Survey of Terminal Users

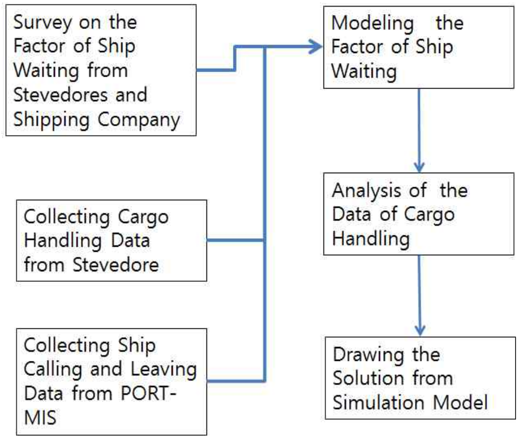
The petrochemical terminal as a case study has two berths of 300m in LOA, alongside the capacity of two 10,000 DWT vessels simultaneously and the handling capacity of two million tons per year.

<Table 1> Specification of Petrochemical Terminal

Berth		No.1	No.2
Alongside Ship Capacity		10,000 DWT	10,000 DWT
Length		115 meters	115 meters
Loading Arm		16 sets	16 sets
Loading Arm Owner		Industry Mgt Agency	Industry Mgt Agency
Using Shipper		Hanhwa Chemical	Hanhwa Chemical
Loading Arm Specification	Flange	6	6
	Pillar	10	10
	Arm	8	8
Line Inch		8	8
Flow Rate (MT/Hr)		300	250

In order to find ship waiting factors, the procedure of research is established as [Fig. 1].

A qualitative analysis of the cause of ship waiting was made by interviewing the Stevedore Company, Shipper and Shipping Company from May 1st, 2017 to June 30, 2017. Question items are listed as <Table 2>.



[Fig. 1] Procedure of Research

<Table 2> Question List for Terminal Users

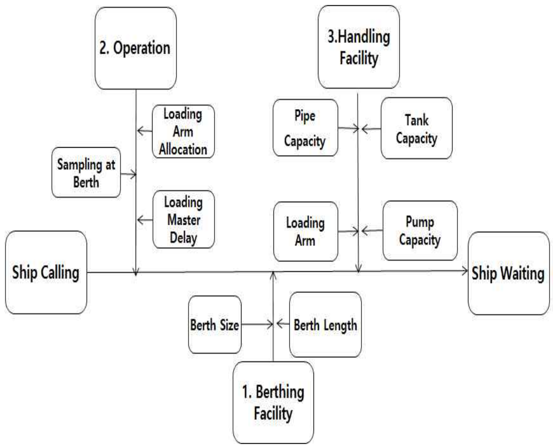
No	Classification	Question Items
1	Berth Facility	Berth size for large ship
2		The number of berths
3	Handling Facility	Pump capacity
4		The diameter of pump line
5		Oil tank storage capacity
6		Oil tank line pressure
7		The number of loading arms
8		The location of oil tank
9		Pipeline layout
10	Operation & Management	Terminal worker skill
11		Cargo sampling at berth
12		Cargo tank cleaning at berth
13		Berth allocation for ship
14		The working time of handling
15		Loading arm allocation to ship

2. The Implication of Survey

According to the survey, the ship waiting in the anchorage are caused by the problems of the berthing facility, the operational skill of cargo handling, and the cargo handling facilities such as loading arm.

Factors related to the operational management system can be listed as the delay of oil sampling, the delay of loading master's arrival, the delay of operator's shift in the manufacturing factory, the delay due to piping chilling before cargo handling in order to reduce pipeline pressure, the unbalanced loading arm allocation. Factors related to the loading and unloading facilities can be listed as the lack of piping capacity, the poor performance of liquefaction facilities,

the lack of loading arms, the lack of tank storage capacity, and the insufficient pump capacity. With the causal finding of ship waiting, the diagram for representing causal effect is shown on [Fig. 2].



[Fig. 2] Causation of Ship Waiting

3. The Analysis of PORT-MIS Data

Data of the petrochemical terminal over 10 years from 2006 to 2015 collected from PORT-MIS is analysed. The data extracted from the database as the factors influencing ship waiting are composed of average ship size, the number of inbound of outbound vessels, total handling volume, and the average cargo handling volume per ship and ship waiting time.

According to the data analysis, the average size of calling vessels increased from 1,658 GT in 2006 to 4,173 GT in 2015, showing an annual growth rate of 10.8%. The number of inbound and outbound vessels of the terminal increased from 156 vessels in 2006 to 759 vessels in 2015, showing an annual average growthe rate of 19.2%. The total handling throughput of the terminal increased from 243,000 MT in 2006 to 1,339,000 MT in 2015, showing an annual average growth rate of 25.5%. Average handling cargo per ship increased from 1,563 tons in 2006 to 2,486 tons in 2015, showing an annual average growth rate of 5.3%. This means that as the scale of the ship becomes larger, the volume of loading and discharging increases proportionately.

The annual ship waiting time increased from 2,032 hours in 2006 to 25,946 hours in 2015, showing an average annual growth rate of 32.7%.

<Table 3> Performance Trend of Oil Terminal

Year	Number of Ship Calling	Total Ship waiting Time	Total Cargo Volume	Ship Size
2006	156	2,032	243,795	1,658
2007	610	13,397	1,220,370	2,533
2008	563	13,863	1,280,003	3,116
2009	688	17,723	1,464,940	3,264
2010	752	28,554	1,614,493	3,391
2011	868	37,525	1,941,933	3,747
2012	838	43,055	2,170,417	4,165
2013	806	27,330	2,028,773	4,078
2014	544	17,395	1,339,423	4,209
2015	759	25,946	1,886,594	4,173
CAGR	19.20%	32.70%	25.50%	10.80%

Additional analysis of correlation between ship waiting time and other factors like the number of calling ships, cargo volume and ship size gives an insight to solve ship waiting problem, As a result of the correlation through 10 years data by SPSS, the number of calling ship has 88.8%, and the cargo handling volume has 91.2% and the ship size has 75.3% relationship with ship waiting time shown on <Table 4>. As the correlation is close to 1 and authors infer that the number of ship and cargo volume factor cause to prolong ship berthing time and to increase ship waiting time.

<Table 4> Correlation of Ship Waiting Time, Number of Calling Ships, Cargo Volume and Ship Size

Relation	Number of Calling Ships	Total Cargo Volume (MT)	Ship Size(GT)
Ship Waiting Time	88.8 %	91.2%	75.3
Significance Probability	0.001	0.000	0.012
Number of Sample	10	10	10

4. Analysis of Stevedore Time Sheet

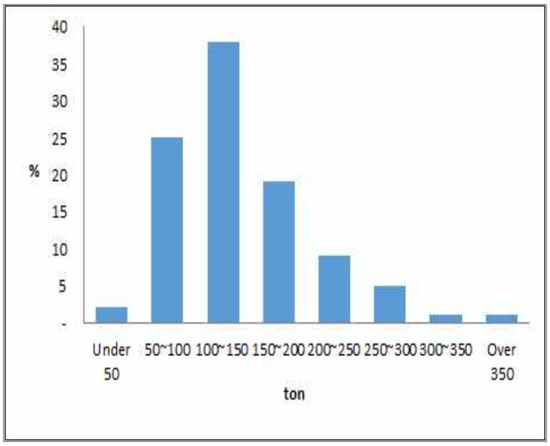
Data of the oil terminal over 3 years from 2013 to 2015 collected from Stevedore's time sheet is analysed. The total number of data records are 1,264 over 3 years, The data extracted from the time sheet as the factors influencing ship waiting composed of “ship name”, “shippers”, “classification of goods”, “cargo handling volume (MT)”, “Gross Tonnage”, “Hose connection time”, “start of unloading work”, “work start time”, “work completion time”, “hose separation time”, and "departure time".

1) Analysis of Ship Handling Productivity

The average ship handling volume per hour is 147.5 MT, the maximum is 2,375.0 MT, and the minimum is 4.0 MT, and the standard deviation is 122.3 MT.

Referring to the distribution of ship handling volume per hour, the percentage under 25 MT is 2%, 50-100 hours is 25%, 100-150 hours is 38%, 150-200 MT is 19%, and over 200 MT is 15%. In the [Fig. 3], X axis represents the interval of ship handling volume per hour and Y axis means the percentage of the number of calling ships on the value of X axis.

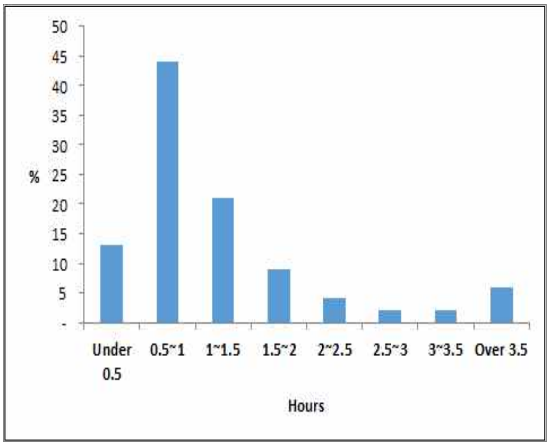
If ship handling volume per hour is improved over the minimum criteria, the ship waiting time will be certainly reduced.



[Fig. 3] Current Ship Handling Volume Interval Percentage (Unit: MT)

2) Analysis of Hose Connection Time of the Vessel

The average hose connection time of the vessel is 1.4 hours, maximum is 19.4 hours, which excluded extreme hose connection time over 20 hours, minimum is 0.2 hours, and the standard deviation is 1.93 hours. Generally speaking, hose connection work is mostly taken short time within 1 or 2 hours, but sometimes it take longer time abnormally. The reason why it takes longer time is explained as there is dual operation like handling two types of cargo on one hose. Referring to the distribution of hose connection time, the percentage under 1 hour is 57%, 1-2 hours is 30% and over 2 hours is 14%. In the [Fig. 4], X axis represents the interval of hose connection time and Y axis means the percentage of the number of calling ships on the value of X axis. As a result of the interview with the shipper and Stevedore, it was expected that the reduction of the hose connection time within 2 hours would dramatically reduce the ship waiting time.



[Fig. 4] Current Hose Connection Time Interval Percentage (Unit: Hours)

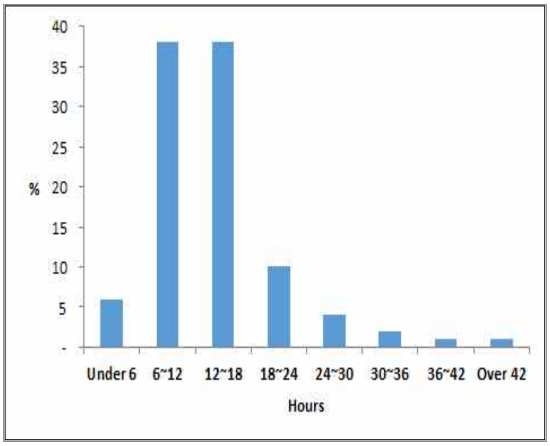
3) Analysis of Ship Berthing Time

The average berthing time of the ship[2)] is 13.6 hours, the maximum is 80.3 hours, and the minimum is 1.2 hours and the standard deviation is

2) The berth time of ship is calculated as the time from when the ship starts to work on the berth to the end of the work. (Patrick M. A. 2008)

7.3 hours.

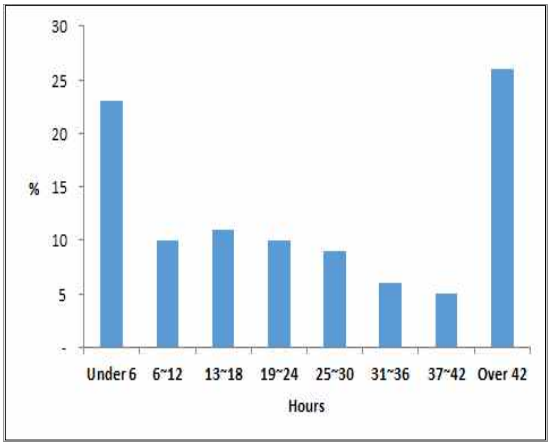
Referring to the distribution of berthing time, the percentage under 6 hours is 6%, 6-12 hours is 38%, and 12-18 hours is 38%, 12-24 hour is 10%, over 24 hours is 7%. In the Fig. 5, X axis represents the interval of ship berthing time and Y axis means the percentage of the number of calling ships on the value of X axis. It is expected that the reduction of the berthing time through the improvement of the cargo handling facilities will reduce ship waiting time.



[Fig. 5] Current Ship Berthing Time Interval Percentage (Unit: Hours)

4) Analysis of Ship Waiting Time

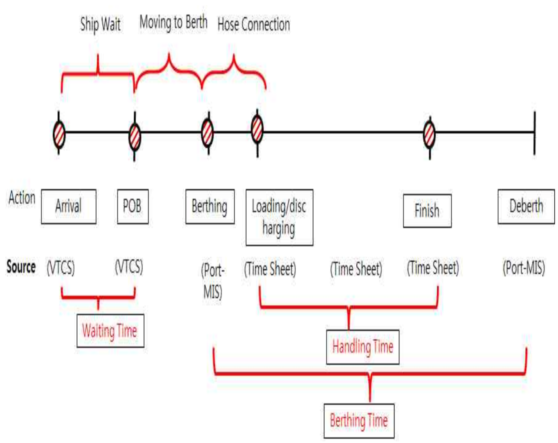
The analysis of the time sheet shows that the average waiting time is 26.2 hours, the maximum is 229.9 hours, the minimum is 0.1 hours, and the standard deviation 27.0 hours. According to the distribution of vessel waiting time, the percentage of waiting ships under 6 hour is 23%, 6-12 hours is 10% and over 30 hours is about 5%. In the [Fig. 5], X axis represents the interval of ship waiting time and Y axis means the percentage of the number of calling ships on the value of X axis



[Fig. 6] Current Ship Waiting Time Interval Percentage (Unit: Hours)

Ⅲ. The Model Simulation for Oil Ship Arrival-Waiting-Berthing-Handling-Leaving

The simulation model of the oil terminal consists of the process of ship arrival, anchoring for berth, berth alongside, hose connection, loading/unloading, hose separation and ship leaving (see [Fig 7]).



[Fig. 7] Process of Ship Berthing-Handling Model

Input and output variables of simulation model are defined in <Table 5>.

<Table 5> Input and Output Information of Simulation Model

	Input Information	Output Information
Simulation Variable	Interval of Vessel Arrival Time Loading/ Unloading Volume, Cargo Handling Time	Calling ships, Throughput(ton), Handling Cargo per Hour (ton/hr), Berth Occupancy (%), Ship Waiting Ratio(%), Ship Long Waiting Ratio(%),

The simulation model requires ship arrival interval time distribution, Ton per call(hereafter referred to as 'TPC')[3] distribution, hose connection time distribution, and cargo handling time per hour distribution depending on TPC. Ship arrival interval time distribution is expressed as "-0.001+380*BETA(0.415, 4.92)"

<Table 6> The Distribution of TPC

	Class	Calling	Percent-age	Distribution of TPC
TPC1	Under 333 MT	333	25.02	41 + 1.11e+003 * BETA(3.55, 1.03)
TPC2	333~ 666 MT	333	25.02	1.15e+003 + WEIB(359, 1.34)
TPC3	666~999 MT	333	25.02	1.97e+003 + LOGN(293, 538)
TPC4	Over 999 MT	332	24.94	2.82e+003 + 7.49e+003 * BETA(0.688, 2.52)

In the Gwangyang port, the calling ship have a wide TPC range from 0 ton to over 1,000 tons. For accurate analysis, TPC is divided into 4 classes such as TPC1, TPC2, TPC3, and TPC4 in <Table 6>. Each TPC has its own handling time and cargo volume per hour like <Table 7>.

<Table 7> The Cargo Handling Time per MT and Cargo Volume per Hour

	Class	Number of Callings	Handling Time per MT (hour)	Cargo Volume Per Hour (MT)
TPC1	Under 333 MT	333	0.76	78.9
TPC2	333-66 MT	333	0.56	106.9
TPC3	666-999 MT	333	0.46	129.6
TPC4	Over 999MT	332	0.29	204.8

Simulation is implemented by ARENA 14.0. With an input value of the simulation, the reliability of program should be verified. he evaluation results show the accuracy of about ∓2% in the Ship Numbers of Calling, Throughput (MT), Handling Cargo per Hour(MT/Hr), Berth Occupancy (%), Ship Waiting Ratio (%) (See <Table 8>).

<Table 8> Simulation Result of Scenario 1

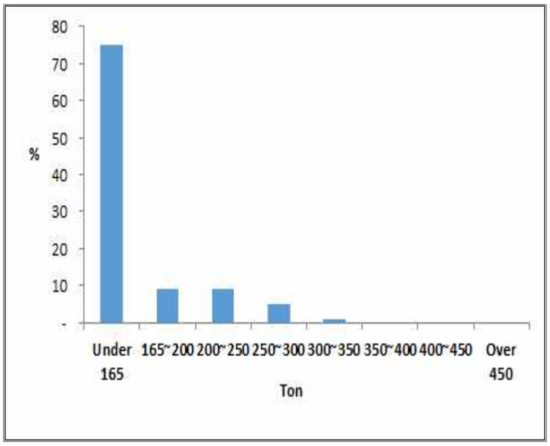
Items	Current Indicator	Simulated Indicator	Accuracy
Calling Ships	1,331	1,298	97.52%
Throughput(MT)	2,958,324	2,966,522	100.28%
Avg. Handling Volume(MT)	130.1	133.0	102.23%
Berth Occupancy Ratio(%)	85.7	84.7	98.83%
Ship Waiting Ratio(%)	165.9	166.0	100.1

3) TPC is an abbreviation of ton per call. When a ship call at port, TPC express the cargo volume for loading and discharging per ship.

Ⅳ. Sensitivity Analysis by Simulation

1. Scenario 1: The Improvement of Pump Capacity.

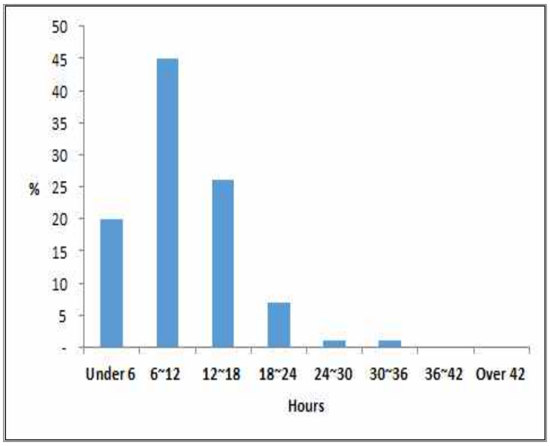
With the pump capacity to more than 15% which has a minimum of 162 MT per hour, and the efficiency of the pump to 90%, the average handling productivity will increase by 180 MT. In the [Fig .8], X axis represents the interval of pump capacity and Y axis means the percentage of the number of calling ships on the value of X axis.



[Fig. 8] Improved Ship Productivity per Hour Interval Percentage (Unit: MT)

As a result of the handling productivity improvement by the simulation, the average berthing time will be improved to 27%. In the [Fig. 9], X axis represents the interval of ship berthing time and Y axis means the percentage of the number of calling ships on the value of X axis.

As a result of the improvement of the pump capacity, the simulation results reveal that average ship waiting time is reduced to 2.3 hour, average ship waiting ratio is reduced to 18.9% and berth occupancy is reduced to 66.5%.



[Fig. 9] Improved Ship Berthing Time Interval Percentage (Unit: Hours)

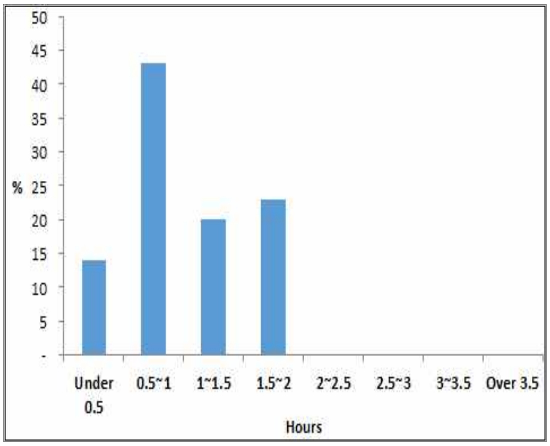
<Table 9> Simulation Results of Scenario 1

Items	Current Indicator	Improved Indicator
Calling Ships	1,331	1,441
Throughput(ton)	2,958,324	3,177,020
Berth Occupancy Ratio(%)	85.7	66.5
Avg. Ship Waiting time(hour)	28.1	2.33
Ship Waiting Ratio(%)	165.9	18.9

2. Scenario 2: The Improvement of Hose Connection Time in Scenario 1.

In Scenario 2, the improvement of the handling pump capacity is the same as that of Scenario 1, and in addition, we added the additional condition in which the hose connection time is limited to within 2 hours.

According to Scenario 2, the simulation results reveal that the average ship waiting time is reduced to 1.98 hours, average ship waiting ratio is reduced to 15.0% and berth occupancy is reduced to 66.5%. In the [Fig .10], X axis represents the interval of hose connection time and Y axis means the percentage of the number of calling ships on the value of X axis.



[Fig. 10] Improved Hose Connection Time Interval Percentage (Unit: Hours)

<Table 10> Simulation Results of Scenario 2

Items	Current Indicator	Improved Indicator
Calling Ships	1,331	1,414
Throughput(ton)	2,958,324	3,173,000
Berth Occupancy Ratio(%)	85.7	64.8
Avg.Ship Waiting time (hour)	28.1	1.98
Ship Waiting Ratio(%)	165.9	15.0

Ⅴ. Conclusion

This study deals with the cause of ship waiting of oil port and to model ways to improve it. The ship waiting in anchorage from the survey are caused by the problems of the berthing facility, the operational skill of cargo handling, and the cargo handling facilities, such as the loading arm. We set two scenarios to reduce ship waiting time. The 1st one is to improve pump capacity to a minium of 162 MT per hour in order to shorten the berthing time.

The 2nd one is to limit hose connection time to within 2 hours based on the 1st scenario. As a result of the improvement of pump capacity, the average ship waiting time is reduced to 2.3 hours from current 28.1 hours, the average ship waiting ratio is reduced to 18.9% from current 165.9% and the berth occupancy is reduced to 66.5% from current 85.7%. If we set two ways to limit hose connection time and improve pump capacity, average ship waiting time is reduced to 1.98 hours from current 28.1 hours, the average ship waiting ratio is reduced to 15.0% and the berth occupancy is reduced to 64.8%, and ship calling is 1,414. Although two types of solution which authors suggested are useful in order to reduce ship waiting time, there remains other ways such as reducing oil tank press-ure, relocation of tank into berth side, and expanding pipe diameter etc. The paper has limitation to expand the horizon to the listed ways as it need a lot of data for analysis of causal effect with quantitative method.

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