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Dock Optimization Planning Gresik Port in 2026-2030

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Abstract

Gresik public port plays the role of a seaport in economic growth, especially to facilitate trade, sources of foreign exchange earnings, importing consumer and capital goods, exporting goods, providing employment opportunities, and so on. The purpose of this research is to forecast the flow of goods through conventional ocean docks and the archipelago in 2026-2030. For this reason, in solving the above problems, a queuing model is used with a distributed ship arrival time testing the Poisson data distribution pattern and an exponentially distributed ship service time with unlimited queues/sources and many services in accordance with testing using the Kolmogorov-Smirnov Gooness of Fit Test. The economic marginal cost of adding one pier unit is IDR 820,199 million, while the total cost for each optimal pier composition per year is always below IDR 820,199 million, and the addition of one unit of the archipelago pier is unlikely to reduce waiting cost at the port. In addition, the addition of the pier is not needed during the years 2026-2030, because the total minimum cost is always smaller than the cost of adding one unit of the pier. For this reason, applying the results of this study, the state will avoid a waste of IDR 820,199 million during 2026-2030.

Keywords: *Planning, Dock Optimization, Gresik Port.*

Introduction

Port is a place consisting of land and/or waters with certain boundaries as a place of government activities and business activities that are used as a place for ships to dock, up and down passengers, and/or loading and unloading goods, in the form of terminals and berths equipped with shipping safety and security facilities and port support activities as well as a place for intra-and/or intermodal transportation movements *(Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 48 of 2021*) [1]. Sea Port is a port that can be used to serve sea transportation activities and/or crossing transportation located at sea or on a river. At the seaport, there is also a terminal, where the terminal is a port facility consisting of a berthing pool and a place for ships to lean or moor, a stacking area, a place to wait and get on and off passengers, and or a place for loading and unloading goods. In addition, there are also Special Terminals, which are terminals located outside the Working Environment Area and the Environment area of Interest of the port, which are part of the nearest port to serve their interests by their main business [2]. However, the important role of sea, river, lake, and crossing transportation will certainly not be realized without the presence of a port that also functions as a node point between land, sea, river, lake, and crossing transportation. The port can be said to be one of the links in the framework of organizing *total transport* or moving goods/passengers from the place of origin to the destination, which requires at least 2 (two) different types of transportation modes. Even in the current development, the port can also be seen as part of logistics activities, whose existence in an area will stimulate economic activities in the area [3].

Gresik public port plays the role of a seaport in economic growth, especially to facilitate trade, sources of foreign exchange earnings, importing consumer and capital goods, exporting goods, providing employment opportunities, and so on. In addition to creating and increasing employment in services related to Transportation in Waters and services related to Ports by providing convenience, protection, and empowerment of micro, small, and medium enterprises, while considering the balance and progress between regions in economic unity [4].

PT Pelindo Gresik, as it plays an important role according to PP No. 50 of 2021, where the Port Business Entity referred to is a business entity whose business activities are specifically in the field of

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Terminal exploitation and other Port facilities. Development for transportation infrastructure is mostly used for the construction of port facilities, especially dock facilities.

Departing from the functions and roles of the Gresik public port above, the role of the Gresik Public Port is needed, considering that it is close to the Tanjung Perak port in Surabaya. This coupled with population growth, regional development, and economic and industrial growth in Gresik Regency and its surroundings, demands a greater role for Gresik Public Port in the future. The need for Gresik port services that are productive, effective, and efficient is one of the factors accelerating regional development in East Java. To realize this desire, the implementation of Gresik public port activities must be able to run well. This means that all facilities available at the port must be used optimally, both in quantity and value of use.

Many factors must be considered to determine whether a port is operating optimally or not. This could be due to a lack of local planners to apply scientific concepts or a lack of direction from higher planning bodies. For this reason, it is necessary to research the optimization of the Gresik public port to reduce real costs and find out when additional docks are needed.

Some of the problems that are of concern in applying the right optimization method to be applied at the Gresik Public Port include the flow of freight transportation at the public port through the container dock is quite large, resulting in an increase in the flow of goods through conventional oceans. In the future, the level of pier usage will increase a lot, while the level of use of the archipelago pier will increase. This will lead to long queues and result in the waiting costs of the archipelago ships increasing. In addition, the dock usage time at public ports for conventional ocean transportation is still too high compared to the effective loading/unloading time of ships. It is necessary to study the factors that influence it. Another issue is related to the composition between conventional oceanic and archipelago docks in the future (during the 2026-2030 period), so that the total economic costs incurred are as low as possible, and whether it is time to add docks.

Based on the description above, this research is interesting to do to forecast the flow of goods through conventional oceanic docks and the archipelago in 2026-2030, so that optimization of conventional and archipelago docks can be carried out period 2026-2030 and provide an overview of the right time to add docks.

Research Methods

This research was conducted in the Gresik Port area, Gresik Regency, East Java. This research was conducted for 3 (three) months starting from June – August 2024. This research uses secondary data taken from PT Pelindo Gresik Branch, Central Bureau of Statistics, and primary data directly in the field, namely at Gresik Port. Data processing using IBM SPSS Statistics 22. Problem-solving techniques need to be supported by methodologies, including forecasting the flow of goods, estimating ship visits, determining the appropriate queuing model, calculating the economic cost of adding a pier, and the optimal location of the pier unit.

Forecasting the flow of goods, the extrapolation model that corresponds to forecasting the flow of goods through conventional ocean, archipelago, and container docks, as in the Linear trend line model, as follows:

$$Y = a + bX,\ a = Y \qquad b = \frac{\sum_{i=1}^{n} Xi\, Y_i}{\sum_{i=1}^{n} X2}$$

Goods flow forecasting method

Forecasting freight flows starts with investing in extrapolation models according to time and characteristics, historical data, freight flows, nominated extrapolation models, statistical testing, extrapolation models used, historical data to determine the price of model parameters, symbolic models with the independent variable being time and the dependent variable being the amount of freight flows, and then determining the forecast of freight flows for 2025-2035.

Goods flow forecasting method

The forecast of ship visits is done by converting the forecast of the flow of goods to the number of ship visits by knowing the amount of cargo per ship. In addition, historical data on ship visits are estimated. This depends on the availability of data.

Determination of the appropriate queuing model

The appropriate queuing model to use depends on the distribution pattern of the ship visit service time data.

Ship service time

Service time is influenced by the speed of loading/unloading goods, access to/from the dock, weather, tonnage carried by ships, and procedures/organization. While the speed of loading/unloading goods is influenced by ship design, type of goods, type/number of goods handling equipment, and shifts/labor.

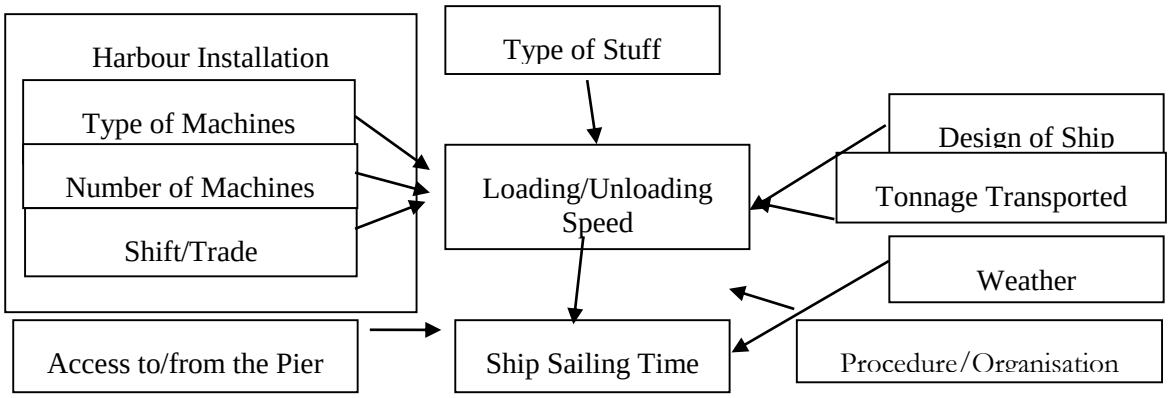


Figure 1. Variables Affecting Ship Service Time

Testing for distribution patterns

Testing the distribution pattern of service time data and ship visits is done using the Kolmogorov-Smirnov Gooness of Fit Test when compared to Chi Square.

Distribution pattern tested

The distribution pattern tested for ship visits was a Poisson distribution, and for ship services was an exponential distribution.

8. Queuing Model used

According to item 6 above, the arrival rate of Poisson distribution ships and the service time of exponential distribution ships with infinite sources, many services.

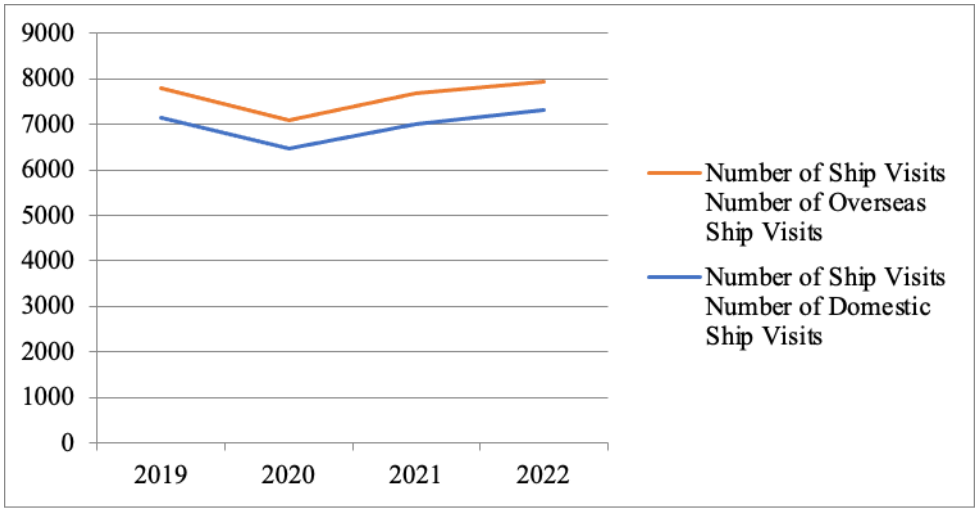
9. Economical ship waiting costs

These costs relate to ships, goods, and containers, such as financial costs

Results and Discussion

Forecasting ship visits

Calculation of ship visit forecasting using the Linear Trend Model using domestic and foreign ship visit data for the period 2019-2022.



Source: PT Pelindo Gresik

Figure 2. Data Chart of Domestic and Foreign Ship Visits at Gresik Port 2019-2022

Calculation of ship visit forecasts at Gresik Post in 2025-2030 using the SPSS program application by finding the value of the variables a and b and inputting the values into the SPSS program with the forecasting model according to the Linear Trend Model formula, namely Y = a +bx. The results of the SPSS calculation of the a and b values are as in Table 1 below.

Table 1. SPSS Calculation Results for a and b values in

Linear Trend Model Calculation

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	6735,500	518,637		12,987	,006
x	100,800	189,379	,352	,532	,648

a. Dependent Variable: in

a = 6735,500

b = 100,800

The results of the forecasting calculation of ship visits at Gresik Port in 2025-2030, as in Table 2, and continued with the calculation of the R value to see the magnitude of the correlation/relationship between the year of visit and the number of overseas ships.

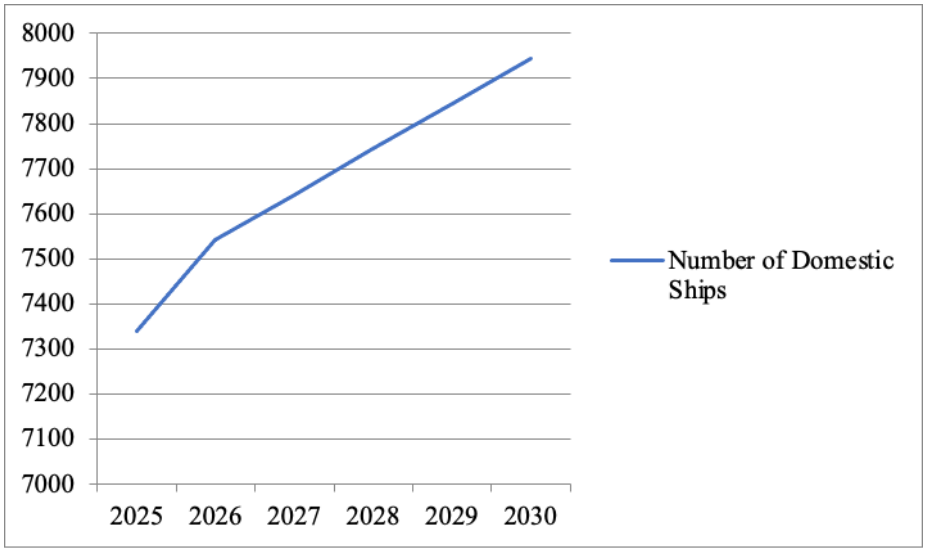


Figure 2. Calculation Data Chart of Domestic Ship Visits 2026-2030

Table 2. Calculation of R-Value of Domestic Ship Visits 2026-2030

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,352[a]	,124	-,314	423,465

a. Predictors: (Constant), x

Based on the calculation results, the R value is 0.352 and the coefficient of determination (R-squared) is 0.124, which implies that the effect of the variable Year (x) on the variable Number of Domestic Ship Visits (y) is **12.4%.** Figure 3 illustrates the forecasting of domestic ship visits in the period 2026-2030.

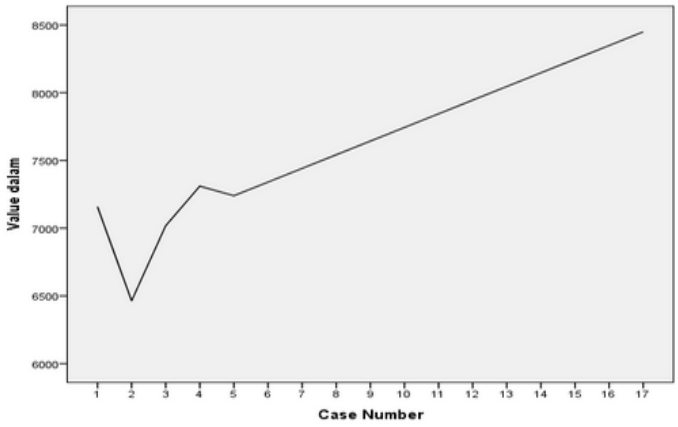


Figure 3. Data Chart of Domestic Ship Visits in 2026-2030

Next, the t value is calculated to see the significance that describes the relationship between the year variable and the number of domestic ship visits. The calculation result of **t count** = 0.532, **t table** = (α/2: n-k-l) then obtained = (0.05/2: 13-1-1) = 2.20. Based on the significance value of the Coefficients table, the significance value is 0.648> 0.05. So, it can be concluded that the year variable (x) does not affect the variable number of domestic ship visits (y). Meanwhile, based on the t value of 0.532 < t table 2.201, it can be concluded that the year variable (x) influences the variable number of domestic ship visits (y). Then, the calculation of the F value distribution is carried out, and the results are obtained as in Table 3.

Table 3. Calculation of F Value Distribution (Anova)

Domestic Ship Visits 2026-2030

Model	Sum of Squares	df	Mean Square	F	Sig.

1	Regression	50803,200	1	50803,200	,283	,648[b]
	Residual	358645,800	2	179322,900		
	Total	409449,000	3			

a. Dependent Variable: in

b. Predictors: (Constant), x

The results of the Anova calculation (distribution of F values) obtained the value of **F count** = 0.283 with a significance level of 0.648> 0.05; it can be concluded that the variable year (x) does not affect the variable number of domestic ship visits (y). Based on the F value of 0.283 < F table 4.75, it is concluded that the year variable (x) influences the variable number of domestic ship visits (y). Based on the results obtained, the same calculation can be done to predict or forecast for the next 13 years for overseas ships.

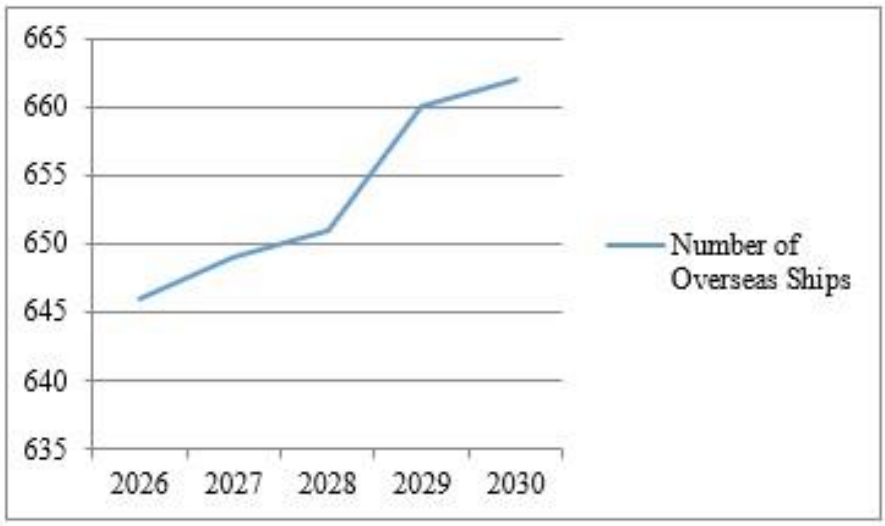


Figure 3: Calculation Chart of Overseas Ship Visits 2025-2030

Table 5. Finding the R Value Overseas Ship Visits 2026-2030

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,185[a]	,034	-,449	21,831

a. Predictors: (Constant), x

Based on the calculation result, the R value is 0.185 and the coefficient of determination (r square) is 0.034, which implies that the effect of the variable Year (x) on the variable Number of Domestic Ship Visits (y) is 03.4%. Figure 4 illustrates the forecasting of overseas ship visits in the period 2026-2030.

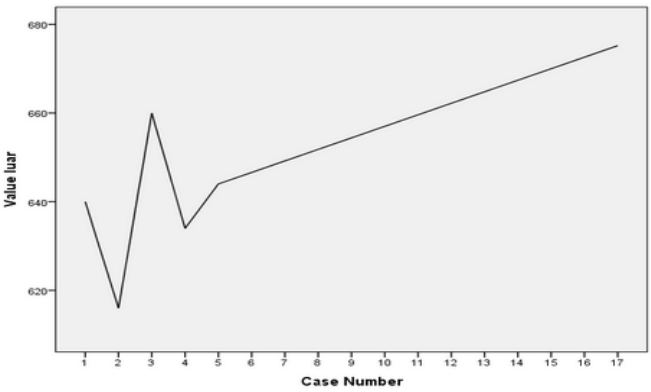


Figure 4, Chart of Overseas Ship Visits 2025-2030

Next, the t value is calculated to see the significance that describes the relationship between the year variable and the number of domestic ship visits. The calculation result of **t count** = 0.266, **t table** = (α/2: n-k-l) then obtained = (0.05/2: 13-1-1) = 2.20. Based on the significance value of the Coefficients table, the significance value is 0.648> 0.05. So, it can be concluded that the year variable (x) does not affect the variable number of overseas ship visits (y). Meanwhile, based on the t value of 0.266 < t table 2.201, it can be concluded that the year variable (x) influences the variable number of overseas ship visits (y). Then the calculation of the F value distribution is carried out, and the results are obtained as in Table 5.

Table 5. Calculation of F Value Distribution (Anova)

Overseas Ship Visits 2026-2030

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33,800	1	33,800	,071	,815[b]
	Residual	953,200	2	476,600		
	Total	987,000	3			

a. Dependent Variable: outside

b. Predictors: (Constant), x

The results of the Anova calculation (distribution of F values) obtained the value of **F** count = 0.071 with a significance level of 0.815> 0.05; it can be concluded that the year variable (x) does not affect the variable number of overseas ship visits (y). Based on the F value of 0.071 < F table 4.75, it is concluded that the year variable (x) influences the variable number of overseas ship visits (y).

Furthermore, the calculation of the flow of goods through the conventional, archipelago, and container docks is carried out by calculating the loading/unloading/import, as in Table 10 below.

Table 6. Forecasting the Flow of Goods

Through Conventional, Nusantara, and Container Docks for the period 2025-2030

Pier Type	Activities	Forecast Model	Calculation Result (tons)
Conventional Dock	Unload	Y = 3,160,400 + 130,827 x 70	Y2025 = 4,063,708 Y2026 = 4,214,535 Y2027 = 4,245,362 Y2028 = 4,376,189 Y2029 = 4,507,016 Y2030 = 4,637,847
	Load	Y = 351,820 + 48,956 X tons	Y_{2025} = 547,644 Y_{2026} = 596,600 Y_{2027} = 645,556 Y_{2028} = 694,512 Y_{2029} = 743,468 Y_{2030} = 792,424
Nusantara Dock	Unload	Y = 456,454 + 52,125 X tons	Y2025 = 664,954

			Y2026 = 717,529 Y2027 = 769,744 Y2028 = 821,959 Y2029 = 874,174 Y2030 = 926,589
	Load	Y = 768,594 + 109,742 X tons	Y2025 = 1,207,562 Y2026 = 1,317,304 Y2027 = 1,427,046 Y2028 = 1,536,788 Y2029 = 1,646,530 Y2030 = 1,756,272

Based on the results of the calculation of forecasting the flow of goods during the period 2025-2030 through conventional oceanic docks (after deducting the results of forecasting the flow of goods through the container dock), and through the archipelago docks, can be seen in Table 7.

Table 7. Forecasting the Flow of Goods through the Ocean Dock

Conventional and Archipelago in 2026-2030

Pier Type		Year				
		2026	2027	2028	2029	2030
Ocean	Unloading (Ton)	3,123,388	3,100,057	3,076,726	3,053,395	3,050,064
	Load (Ton)	438,047	469,172	500,297	531,422	562,547
Number I		**3,561,435**	**3,569,229**	**3,577,023**	**3,584,817**	**3,592,611**
Nusantara	Unloading (Ton)	717,529	769,744	821,959	874,174	926,389
	Load (Ton)	1,317,304	1,427,046	1,536,788	1,646,530	1,756,272
Number II		**2,034,833**	**2,196,790**	**2,358,747**	**2,520,704**	**2,682,661**
TOTAL		**5,596,268**	**5,766,019**	**5,955,770**	**5,105,521**	**6,275,272**

Graphically, the data in Table 7 can be seen in Figures 5 and 6 below.

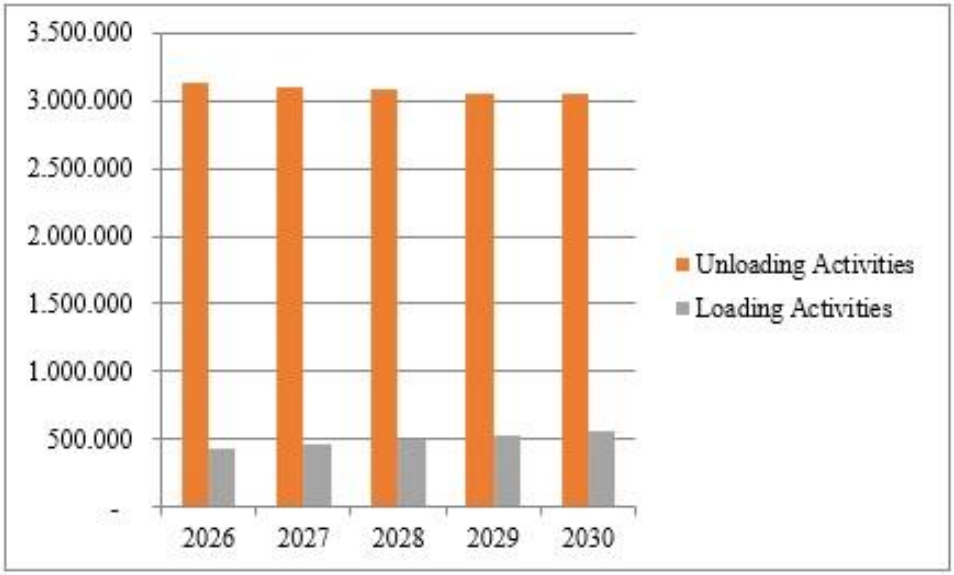


Figure 5. Chart of Conventional Ocean Dock Visit of Overseas Ships 2025-2030

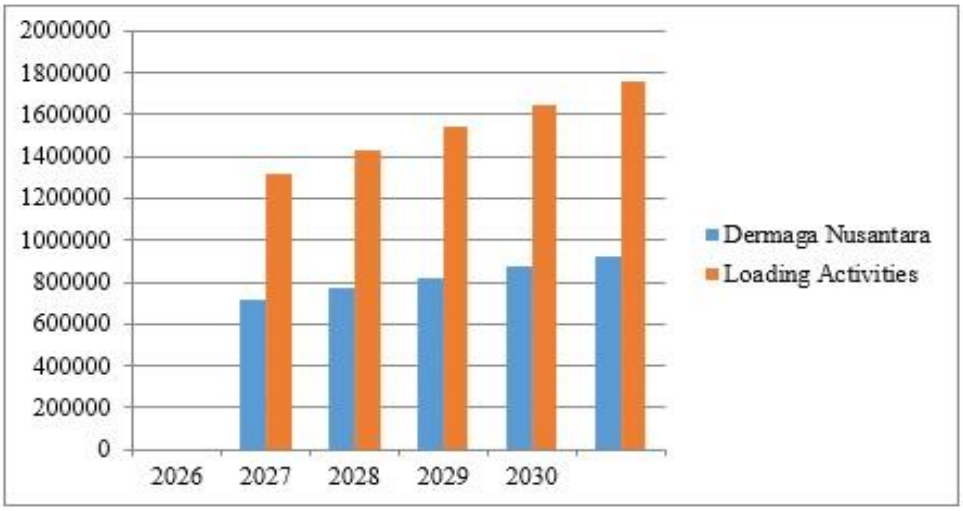


Figure 6: Chart of Archipelago Dock Visits for Overseas Ships 2025-2030

Optimization of conventional and archipelago docks

Optimization with a queuing model

The first thing to do is to calculate the estimated ship visits during the period 2025-2030. The results of estimated number of ship visits (JKK) obtained 107 ships/year for all classes of ship sizes. To analyze the general characteristics of port services, the queuing theory in port shipping. The results of the calculation of data forecasting the flow of general goods through conventional oceanic docks and the archipelago in 2026-2030, with Conventional Ocean Ship Visits data obtained five days each month, show by 16%. As for the service time of conventional oceanic ships and the archipelago, each is 10% of each month's estimated ship visits. To test the validity of the success of the Poisson distribution of ship visits and the exponential distribution of ship service time, the *Kolmogorov Smirnov Good of Fit Test* is used using the Poisson distribution formula $f(Y) = \frac{\lambda^Y e^{\lambda}}{Y!}$, then for conventional ocean liner visits it is obtained by λ= 353/60 = 4,217 ships/day with a sample size of n = 60 and a price of e = 2.718. Archipelago ship visits for λ=339/60 = 5,65 ships/day. While for ship services using the Exponential distribution formula f (t and under T) = f (X) = [$e^{(-t/m-)}$ $e^{-(T/m)}$], for conventional ocean liner services, obtained 3.446 days/ship. Meanwhile, for archipelago ship services, 3.5 days/ship is obtained. This calculation is with data in 2023, so based on the distribution analysis above, it can be concluded that the queuing model that is suitable for use in analyzing the waiting time of ships at Gresik port for conventional and archipelago ocean freight transportation is a queuing model with Poisson-distributed ship arrivals and exponentially distributed ship service times, unlimited queues/sources, many services. The distribution of ship arrivals and service times during the period 2026-2030 is assumed to be the same as in 2023, namely the Poisson and Exponential distributions.

Number and composition of docks 2025

The number of docks in 2025 for conventional ocean-going vessels is 30 units, with an average length of 141 meters, and for archipelago vessels is 30 units, with an average length of 76 meters mentioned above. While the average length of conventional ocean-going vessels is 129 meters and archipelago vessels 66 meters, meaning that there is still a dock length for safety and distance, an average of 12 meters for conventional ocean-going docks and 10 meters for archipelago docks. The ratio between the length of conventional oceanic and archipelago docks is almost 2 to 1; in other words, one unit of conventional oceanic dock can be converted into two units of archipelago dock.

Economical Ship Waiting Costs at Port

Conventional ocean liner costs consist of waiting costs associated with ships, goods, and containers. The waiting cost of a conventional ocean liner ship is approximated by the ship cartel cost as an alternative cost, which is its economic cost. Since financial data from the company is not available, a manual calculation is carried out using the following formula:

Standard conversion factor SCF = 0.9648

Foreign exchange shadow price SER = OER/SCF = IDR 1000/0.948 = IDR 1036

Charter price per day = Charter price per month x ship DWT x 12 x IDR 1036

365 days

For 2000 DWT vessels:

Charter price per day = US$27.26 x 2000 x 12 x IDR 1036 = IDR 1880 million

365

Using the same method for other vessel sizes, the economic charter price is obtained as shown in Table 8.

Table 8. Economic charter price of ocean-going vessels

General freight transportation per day

Ship Size DWT	Charter price per day (BEK) (IDR)
2000	1880000
4000	2839000
6000	3356000
8000	4119000
10000	4533000
12000	4631000
16000	5063000
26000	5659000
42000	7796000

Furthermore, the calculation of ship waiting costs using a non-linear continuous function of ship waiting costs BEK = 73,960 $(DWT)^{(0.438)}$ where BEK is the economic cost of the ship. Through the calculation, the correlation coefficient value of 0.987 is obtained, which can be concluded that the cost of waiting for the ship is very well positively correlated with the size of the ship (DWT), so the non-linear continuous function is well used to calculate the average charter cost of the ship size class. For example, for ship size class I (average 2,000 DNT), then BEK = 73,960 $(2{,}000)^{0.458}$ = IDR 2,065,000, and in the same way for other ship size classes during the period of 2026-2030.

The cost of waiting for goods due to ships waiting at the port is approximated by the cost of capital embedded in the goods, with the formula $BM = \frac{\text{NB x I}}{365}$. The value of goods is approximated by the average value of goods (FOB) and imported goods (CIF) within Gresik Port in 2025. The alternative interest rate for economic capital is taken as the commercial lending rate of international banks at 12%. This data shows that the number of imports through Gresik Port from January – June 2025 amounted to 2,416,827 tons with a value of US$2,082,144,797, and export goods amounted to 314,293 tons with a value of US$97,504,060. For information, export goods to import/export goods are 12% in 2026, 13% in 2027, 14% in 2028, 15% in 2029, 16% in 2030. So that the BM obtained is IDR 183,944/ship/day.

The cost of waiting for containers due to ships waiting at Gresik port is approximated by the rental price of containers from abroad at an average of US$3 per TEU/ Twenty Equivalent Unit. Container loading and unloading at conventional ocean ports in 2023 is 45,392 units, in 2024, 52,170 units, and in 2025 is 57,766 units, obtaining IDR 1,440,445/ship/day.

Annual Economic Cost

The annual economic cost can be calculated based on the engineering life of the civil building, estimated at 30 years, the crane estimated at 10 years, and the forklift estimated at 7 years. Consultant fees are included in the cost of the civil works. Economic money interest is 12% a year. Annual economic cost

$BESK_1$ and $BESK_2$ = IDR 1,468,343,520, - $\frac{\text{x } 0.12\ (1 + 0.12)^{10}}{(1+0.12)^{10} - 1}$ = IDR 256,873,550, -

$BESK_3$ = IDR 1,468,358,926, - $\frac{\text{x } 0.12\ (1 + 0.12)^{7}}{(1+0.12)^{7} - 1}$ = IDR 321,740,107, -

$BESK_4$ = IDR 3,132,393,648,398, - $\frac{x\ 0.12\ (1 + 0.12)^{30}}{(1+0.12)^{30} -1}$ = IDR 182,285,535, -

$BESK_5$ = IDR 819,438,928,507, -

Total annual economic cost of adding one dock unit to the archipelago:

= ∑ BESKj

= IDR 256,873,550, - + = IDR 321,740,107, - + IDR 182,285,535, - + IDR 819,438,928,507, - = IDR 820,199,827,699, -

Optimal Allocation of Dock Units in 2026-2030

The queuing model used is a queuing model with ship arrivals Poisson distribution and exponential service time with unlimited queues/sources, many services.

1) The number of ship visits per year, JKK, can be obtained
2) Ship visits per day λ is the quotient of the number of ship visits per year, JKK, with the number of days during the year, 365 days
3) Ship service level per day μ is the average construction price for 2019-2023
4) Economic cost of ships waiting at BT port
5) The number of berths varies with the formula S_s= 30 – n for conventional ocean berths and S_n = 30 + 2n for archipelago berths.
6) 6. The forecast of the flow of goods through the conventional ocean docks and the archipelago in 2026 – 2030 is as follows:

Table 9: Economic charter price of conventional ocean-going vessels

Year	Ocean Pier Conventional (Unit)	Dock Nusantara (Unit)
2026	26	38
2027	26	38
2028	25	40
2029	25	40
2030	24	42

Conclusions and Suggestions

Conclusions

Forecasting the flow of goods through conventional oceanic and archipelago docks in 2026-2030, namely in 2026-2027 conventional oceanic docks 26 units and archipelago docks 38 units, in 2028-2029 conventional oceanic docks 25 units and archipelago docks 40 units, while for 2030 conventional oceanic docks 25 units and archipelago docks 40 units. For this composition, the optimal allocation of one unit of conventional oceanic dock and the archipelago of Gresik port during 2026-2030.

While the economic marginal cost of adding one pier unit is = IDR 820,199,827,699, the total cost for each optimal pier composition per year is always below IDR 820,199,827,699. This illustrates that the addition of one unit of the archipelago pier is unlikely to reduce waiting costs at the port. So, if the results of this study are determined, the state will save IDR 820,199,827,699 during the period 2026-2030. Therefore, the optimal allocation of conventional oceanic and archipelago dock units at Gresik port during 2026-2030.

Suggestions

To make this research more perfect, it is necessary to separate the ship data according to the type of goods carried and the type of dock used. In addition, the data collection system is refined so that it can support planning properly. It is also necessary to have a consultant who handles studies on ports and transportation in general; presumably, the method of determining economic costs is usually subjective. For that to include the cost component of goods and containers in the port study.

References

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