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OPTIMIZATION OF PORT TERMINAL OPERATIONS: A CASE STUDY OF INTERNATIONAL CARGO HANDLING

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ABSTRACT
Maritime logistics plays a crucial role in global trade, with port terminal efficiency being a critical factor in supply chain performance. While extensive research has addressed container terminal optimization, studies focusing on non-containerized cargo terminals in developing countries remain limited. This study examines the operational efficiency of international cargo handling at Jamrud Terminal, Tanjung Perak Port, Indonesia's second-largest port. Using a quantitative approach, we analyze stevedoring activities, Berth Occupancy Ratio (BOR), and loading-unloading performance through time series decomposition forecasting. Our 2024 forecasting results reveal that general cargo and dry bulk cargo handling performance falls below international standards, with a concerning BOR level of 85%. The study proposes optimization scenarios focusing on operational restructuring and facility enhancement, contributing to the broader literature on non-containerized terminal optimization in emerging economies. Our findings provide practical implications for port authorities and terminal operators in similar contexts, particularly in addressing the challenges of increasing cargo volumes while maintaining operational efficiency.

Keywords: berth occupancy ratio; developing countries; maritime logistics; non-containerized cargo; port operations optimization; time series decomposition

INTRODUCTION
Maritime logistics serves as the backbone of more than 80% of global trade volume, with ports serving as critical nodes in international supply chain networks (Geneva 2021). Port of Indonesia's contribution to reducing national logistics costs is to implement a strategy to shorten Port Stay and cut Cargo Stay by implementing service performance standards set by the government (Safuan 2023). In Indonesia, the transportation and warehousing sector has shown remarkable growth, reaching 10.33% (BPS 2024). This significant growth underscores the sector's vital role in driving national economic development, particularly through maritime infrastructure. However, this growth also presents substantial challenges for port operators, especially those managing non-containerized cargo terminals, where operational complexities often exceed standard container handling (Caliskan and Ozturkoglu 2016; Notteboom and Rodrigue 2006).

While much research has been conducted on port operations globally, there are still significant gaps in our understanding of the optimization of non-containerized cargo terminals, particularly in the context of developing countries (Edih, Faghawari, and Agboro 2023). (Danladi et al. 2024) found that container ports in developing countries are often inefficient due to technical issues rather than port size, and larger ports are not necessarily more efficient. A literature review by (Zhang, Yang, and Luo 2024) analyzed studies on port efficiency and found that the majority of studies assess port efficiency from the perspective of port authorities, managers and operators, with a primary focus on container terminals. Few studies analyzed port efficiency from the perspective of users and the public, and paid attention to the conflict between port service levels and profitability.

Review by (Jeh et al. 2022) highlights that terminals in developing countries often face challenges such as limited infrastructure, resource constraints, and rapidly increasing cargo volumes. However, research addressing these unique operational challenges remains limited in the current academic literature. While the existing literature has thoroughly examined container terminal automation (Zhou and Suh 2024), efficiency metrics (Bartosiewicz, Kucharski, and Miszczyński 2024), tourism port (Meita et al. 2023) and environmental impact at the port (Durlik et al. 2024; Dwipayana and Darmayanti 2024).

Limited attention has been paid to the unique operational challenges facing non-containerized cargo terminals in developing countries. These terminals often operate under certain constraints, including infrastructure limitations, resource constraints, and rapidly increasing cargo volumes, creating complex optimization challenges that are still not adequately addressed in the current academic literature. (Setiono; 2008). Tanjung Perak Port, positioned as Indonesia's second largest port, exemplifies these challenges while serving as an important gateway for trade flows to eastern Indonesia. Jamrud International Terminal, which is specifically designated to handle international non-containerized cargo and bulk cargo, faces increasing pressure to maintain and improve operational efficiency amid growing trade volumes.

Tanjung Perak Port is the second largest port in Indonesia after Tanjung Priok Port in Jakarta and also as a trade center to eastern Indonesia. Tanjung Perak Port is managed by PT Pelabuhan Indonesia (Persero) 3 Surabaya Branch as a port facilitator. The International Jamrud Terminal is part of the Jamrud Terminal at Tanjung Perak Port, which consists of the North Jamrud Terminal and West Jamrud Terminal and has a special function to carry out goods services in the form of international cargo and bulk. The important role of adequate port facilities in supporting logistics distribution cannot be ignored, especially in the face of an increasingly complex future. The operational performance at the port is also one of the keys to the success of a port as the starting point and end point of an efficient supply chain. Thus, the effectiveness of port loading and unloading activities can enable the smooth movement of goods from one place to another smoothly. Therefore, to help optimize the delivery of adequate logistics and have a crucial role in the smooth flow of logistics distribution and sustainable economic growth into the future, the author is interested in making research on international goods loading and unloading activities at Jamrud Terminal.

The complexity of these challenges is further compounded by the unique characteristics of handling non-containerized cargo, which requires specialized equipment, varied handling procedures, and flexible operational strategies. (Haralambides 2019. Handling non-containerized cargo can increase operational time compared to standard containerized cargo (Rattanakunuprakarn et al. 2024; Eliufoo Muro, Mbeba Meli, and Pastory Mwisila, n.d.). In contrast to containerized cargo operations that benefit from standardized handling procedures and equipment (Filina-Dawidowicz and Kostrzewski 2022), non-containerized cargo terminals must adapt to different cargo types, sizes, and handling needs.

The purpose of this study is to determine the condition of the facilities and performance of the loading and unloading of goods on stevedoring activities and to know the forecasting of the flow of goods and ship visits that carry out loading and unloading as well as the performance conditions on the loading and unloading of international goods at Jamrud Terminal so as to find out the optimization solution to the international loading and unloading activities of Jamrud Terminal in the future. The results of this study are expected to provide benefits and be used as suggestions or recommendations for PT Pelindo (Persero) Multi Terminal Jamrud Nilam Mirah

Branch, especially at the International Jamrud Terminal in developing and optimizing international loading and unloading activities so as to maximize the services provided by the company as a multi terminal manager and facilitator of Tanjung Perak Port.

METHOD

This research adopts a quantitative approach conducted at the International Jamrud Terminal, Tanjung Perak Port, Surabaya, from April to August 2024. Primary data: Field observations and interviews covering equipment, dock length, working gang, service times, and SOPs. Secondary data: Reports, statistics, and Pelindo publications on cargo flow and ship visits over the past two years. Performance Indicators

1. Tonnage per Gang per Hour (T/G/H): Measures cargo handling productivity.
2. Yard & Shed Occupancy Ratios (YOR & SOR): Assess utilization of storage areas.
3. Berth Occupancy Ratio (BOR): Measures berth usage intensity.
4. Berth Throughput (BTP): Freight volume per meter of berth length.
5. Dock Length Requirement: Based on ship LOA and spacing standards.

The study uses time series decomposition (additive & multiplicative models) to project cargo flows and vessel visits. The method breaks data into trend, seasonal, and residual components (Azizah, 2021; Nugraha, 2023). Forecasting accuracy is evaluated using:

1. MAPE (Mean Absolute Percentage Error)
2. MAD (Mean Absolute Deviation)
3. MSE (Mean Squared Error)
4. R-squared (R^2): Indicates model fit; >0.75 considered strong.

RESULT AND DISCUSSION

Existing Condition

Based on the results of direct observation at the International Jamrud Terminal, there are four types of non-containerized international goods packaging that are loaded and unloaded at the dock, namely general cargo, bag cargo, dry bulk and liquid bulk. The terminal facilities are in the form of docks, stacking yards and warehouses. As for loading and unloading equipment, there are lifting equipment and loading and unloading aids owned by Pelindo in supporting loading and unloading activities. The observation results show that loading and unloading equipment is still suitable for use in loading and unloading activities with a readiness level of 80%. This is also supported by the cooperation between Pelindo and its subsidiaries which can carry out periodic maintenance of loading and unloading equipment. Based on the monthly performance report of the international freight terminal, it is known that the average length of the ship (LOA) is 148 meters, with a total of 6 moorings.

Based on Keputusan Kepala Kantor Otoritas Pelabuhan Utama Tanjung Perak No. HK.2.6/01/04/OP.TPr-2020 Tentang Standar Kinerja Pelayanan Operasional Pelabuhan Tanjung Perak, port operational performance standards that must be met by terminal operators in Tanjung Perak including the Jamrud Terminal. The following are guidelines for loading and unloading goods performance standards as well as utility standards for facilities and operational readiness at the Jamrud Terminal.

1. Performance Standards for Loading and Unloading Non-Containerized Goods

The indicators used in measuring the standard performance of loading and unloading non-containerized goods include General Cargo (GC), Bag Cargo (BC), Dry Bulk (DB), Liquid Bulk (LB), Unitized (UN), and lifestock. The following is the performance standards for loading and unloading non-containerized goods at the Jamrud Terminal in table 3.

Table 1.
Performance Standards for Loading and Unloading Non-Containerized Goods

No.	Service Performance	Performance Standards	Unit
1.	*General Cargo* (GC)	120	T/G/H
2.	Bag *Cargo* (BC)	40	T/G/H
3.	Dry Bulk (DB)	140	T/G/H
4.	Liquid Bulk (LB)	125	T/G/H

Source: (Tanjung Perak Port Authority, 2020 and Jamrud Terminal SOP, 2024)

2. Facility Utility Standards and Operational Readiness

This indicator consists of Berth Occupancy Ratio (BOR), Yard Occupancy Ratio (YOR), Shed Occupancy Ratio (SOR), and operational readiness. The following are the standard utility facilities and operational readiness of the Jamrud Terminal presented in table 4.

Table 2.
Utility Standards for Facilities and Operational Readiness

No.	Service Performance	Performance Standards	Unit
1.	BOR	70	%
2.	YOR	50	%
3.	SOR	65	%
4.	Operational Readiness	80	%

Source: (Tanjung Perak Port Authority, 2020)

Forecasting Results

Forecasting is carried out to forecast the flow of goods and the number of ship visits in the next 1 year (Year 2024) based on historical data of 24 months from the research time using the time series decomposition method which was distinguished based on the type of goods packaging at the International Jamrud Terminal. The following is presents the forecast results for each type of goods which is divided into 4 categories.

1. Forecasting Goods Flows and General Cargo Ship Visits

Based on the results of the forecast error comparison, the goods flow and ship visits of general cargo is more suitable using the time series decomposition forecasting method of the additive type. This is because forecasting general cargo using the additive type is the least error value. The following are the results of the general cargo forecasting errors comparison in table 3.

Table 3.
Comparison of General Cargo Forecasting Error Values

No.	Error Peramalan	Multipllicative Type		Additive Type	
		Goods Flow	Ship	Goods Flow	Ship
1	MAPE	22%	20,25%	20%	19,92%
2	MAD	44111	3,23	37769	3,17
3	MSE	4637740248	27,58	3388655993	24,51
4	R-squared	0,8052		0,7942	

Source: (Author Data Processing, 2024)

2. Forecasting Goods Flows and Bag Cargo Ship Visits

Based on the results of the comparison of forecasting errors, the goods flow and ship visits of bag cargo is more suitable using the additive type time series decomposition forecasting method. This is because bag cargo forecasting using additive type has the least error value. The following are the results of the bag cargo forecasting errors comparison in table 4.

Table 4.
Comparison of Bag *Cargo* Forecasting Error Values

No.	Error Peramalan	Multipllicative Type		Additive Type	
		Goods Flow	Ship	Goods Flow	Ship
1	MAPE	125%	51,48%	44%	35,84%
2	MAD	23181	0,98	10325	0,81
3	MSE	1507215189	2,84	220897885	1,39
4	R-squared	0,9134		0,9405	

Source : (Author Data Processing, 2024)

3. Forecasting Freight Flows and Dry Bulk Vessel Visits

Based on the results of the comparison of forecasting errors, the goods flow and ship visits of dry bulk cargo is more suitable using the time series decomposition forecasting method of additive type. This is because the forecasting of dry bulk loads using the additive type has the least error value. The following are the results of the dry bulk forecasting errors comparison in table 5.

Table 5.
Comparison of Dry Bulk Forecasting Error Values

No.	Error Peramalan	Multipllicative Type		Additive Type	
		Goods Flow	Ship	Goods Flow	Ship
1	MAPE	32%	26,28%	31%	25,96%
2	MAD	31138	1,84	29031	1,95
3	MSE	2071506893	10,16	1843509186	8,47
4	R-squared	0,8972		0,8762	

Source: (Author Data Processing, 2024)

4. Forecasting Freight Flows and Liquid Bulk Vessel Visits

Based on the results of the comparison of forecasting errors, the goods flow and ship visits of liquid bulk cargo is more suitable using the multiplicative time series decomposition forecasting method. This is because forecasting liquid bulk cargo using the multiplicative type has the smallest error value. The following are the results of the liquid bulk forecasting errors comparison in table 6.

Table 6.
Comparison of Liquid Bulk Forecasting Error Values

No.	Error Peramalan	Multipllicative Type		Additive Type	
		Goods Flow	Ship	Goods Flow	Ship
1	MAPE	30%	26,02%	30%	26,42%
2	MAD	4572	0,50	4666	0,51
3	MSE	43646174	0,51	48428878	0,55
4	R-squared	0,8161		0,8007	

Source: (Author Data Processing, 2024)

Based on the forecast results, it can be concluded that general cargo, bag cargo, and dry bulk are more suitable for using additive type time series decomposition forecasting. Meanwhile, for liquid bulk loads, it is more suitable to use multiplicative type time series decomposition forecasting.

Projected Cargo Flow and Number of Ship Visits

The results of forecasting the flow of goods in accordance with the type of forecasting of each cargo are presented in table 9 as a forecast projection of the flow of goods as follows.

Table 7.
Projection of Goods Flow Forecasting Results

No.	Period	Type of Goods Packaging (tons)				Total Goods Flow (tons)
		GC	BC	CK	CC	
1	Jan-24	217.941	56.858	127.355	11.524	413.678
2	Feb-24	56.214	72.070	68.818	12.262	209.364
3	Mar-24	299.083	85.586	93.482	17.051	495.202
4	Apr-24	151.918	40.138	87.426	11.706	291.188
5	May-24	146.308	78.215	40.295	0	264.818
6	Jun-24	207.296	89.873	71.193	19.468	387.830
7	Jul-24	195.405	69.589	71.814	21.264	358.072
8	Aug-24	182.207	85.019	37.226	11.328	315.780
9	Sep-24	145.259	70.597	44.178	9.035	269.069
10	Oct-24	47.874	74.254	95.445	14.521	232.093
11	Nov-24	47.397	72.890	85.661	15.119	221.067
12	Dec-24	150.083	71.920	47.142	9.812	278.957

Source: (Author Data Processing, 2024)

Meanwhile, the results of forecasting the number of ship visits in accordance with the type of forecasting for each cargo are presented in table 8 as a projection of the number of ship visits as follows.

Table 8.
Results of Forecasting the Number of Ship Visits

No.	Period	Number of Ship Visits				Total ships
		GC	BC	CK	CC	
1	Jan-24	19	5	13	2	39
2	Feb-24	7	7	6	2	22
3	Mar-24	24	7	10	3	44
4	Apr-24	15	3	8	2	28
5	May-24	14	5	3	0	22
6	Jun-24	17	8	8	3	36
7	Jul-24	20	6	8	3	37
8	Aug-24	21	7	4	2	34
9	Sep-24	16	6	5	1	28
10	Oct-24	10	7	7	2	26
11	Nov-24	4	6	9	2	21
12	Dec-24	13	6	6	1	26

Source: (Author Data Processing, 2024)

Projected Loading and Unloading Performance Conditions

From the results of goods flow and the number of ship visits projection, it is further possible to calculate the loading and unloading performance of non-container goods per work gang on one ship for the four types of cargo in the January-December 2024 period in table 9.

Table 9.
Calculation of Loading and Unloading Goods Performance

No.	Period	Loading and Unloading Performance (T/G/H)				Valuation			
		GC	BC	CK	CC	GC	BC	CK	CC
1	Jan-24	155	43	89	128	Good	Good	Not good	Good
2	Feb-24	109	39	104	136	Pretty good	Pretty good	Not good	Good
3	Mar-24	168	46	85	126	Good	Good	Not good	Good
4	Apr-24	137	51	99	130	Good	Good	Not good	Good
5	May-24	141	59	122	0	Good	Good	Not good	-
6	Jun-24	165	43	81	144	Good	Good	Not good	Good
7	Jul-24	132	44	82	158	Good	Good	Not good	Good

No.	Period	Loading and Unloading Performance (T/G/H)				Valuation			
		GC	BC	CK	CC	GC	BC	CK	CC
8	Aug-24	117	46	85	126	Pretty good	Good	Not good	Good
9	Sep-24	123	45	80	201	Good	Good	Not good	Good
10	Oct-24	65	40	124	161	Not good	Good	Not good	Good
11	Nov-24	160	46	87	168	Good	Good	Not good	Good
12	Dec-24	156	45	71	218	Good	Good	Not good	Good

Source: (Author Data Processing, 2024)

Based on the results of loading and unloading performance calculation in table 12, it can be seen that there is a loading and unloading performance in October 2024 for general cargo and January-December 2024 for dry bulk cargo that is still below standard. With the estimated performance of loading and unloading goods that are below standard in the future, it is necessary to improve or optimize the performance of the terminal.

Projection Dock Utility Condition

Based on the results of the projected number of ship visits per month, an analysis of the calculation of the utility condition of the BOR dock for the January-December 2024 period can be carried out which is presented in table 10 as follows.

Table 10.
BOR and BTP Utility Calculation

No.	Period	BOR	BOR Assessment
1	Jan-24	75%	Pretty good
2	Feb-24	43%	Good
3	Mar-24	85%	Not good
4	Apr-24	54%	Good
5	May-24	43%	Good
6	Jun-24	70%	Good
7	Jul-24	72%	Pretty good
8	Aug-24	66%	Good
9	Sep-24	54%	Good
10	Oct-24	50%	Good
11	Nov-24	41%	Good
12	Dec-24	50%	Good

Source: (Author Data Processing, 2024)

Based on the results of the calculation in table 12, it can be seen that the dock utility is classified as high and declared not good in March 2024 with the achievement of 85% utility which is 10% above the 70% standard set by the Tanjung Perak Port Authority. Therefore, to prevent high overutility in the future, it is necessary to develop and repair dock utilities.

Optimized Loading and Unloading Performance

Based on the projected conditions of non-container loading and unloading performance in table 11, it is necessary to optimize so that the loading and unloading performance for general cargo in October 2024 and for dry bulk cargo in January-December 2024 can be optimal and in accordance with the performance standards set by the Tanjung Perak Port Authority. Improving loading and unloading performance can also attract customers to load and unload non-container international goods at the Jamrud Terminal. The optimization solution provided in the operational of stevedoring loading and unloading activities by reducing the number of work alleys to improve loading and unloading performance which is still below the standards of each type of cargo load. The following is a calculation of optimizing loading and unloading performance by reducing the number of work alleys on general cargo and dry bulk cargo.

1. Optimization of General Cargo Loading and Unloading Performance

The month of October 2024 has a general cargo flow of 47,874 tons with a total of 10 ship visits, as well as an effective loading and unloading time (ET) of 37 hours. In August 2024, the number of optimization gangways is 1 gang. The following is the calculation:

$$Km\ GC = \frac{V_m}{G \times ET} = \frac{(47.874:10)}{1 \times 37} = \text{ 129 T/G/H > 120 T/G/H (good performance)}$$

2. Optimization Dry Bulk Loading and Unloading Performance

All months in 2024 have poor loading and unloading performance levels. Such as December 2024 which has a dry bulk cargo flow of 47,142 tons with a total of 6 ship visits, and an effective time (ET) of 55 hours. The number of initial gangways is 2 gangways, while the number of optimization gangways is 1 gangway. The following is the calculation:

$$Km\ CK = \frac{V_m}{G \times ET} = \frac{(47.142:6)}{1 \times 55} = \text{ 143 T/G/H > 140 T/G/H (good performance)}$$

So, with the results of optimization with the reduction of the number of gangways has a good impact on those months so that there is an increase in loading and unloading performance, which can be shown in table 13 as follows.

Table 11.
Results of Optimizing Loading and Unloading Performance

No	Period	Loading and Unloading Performance (T/G/H)				Valuation			
		GC	BC	CK	CC	GC	BC	CK	CC
1	Jan-24	155	43	178	128	Good	Good	Good	Good
2	Feb-24	109	39	209	136	Pretty good	Pretty good	Good	Good
3	Mar-24	168	46	170	126	Good	Good	Good	Good
4	Apr-24	137	51	199	130	Good	Good	Good	Good
5	May-24	141	59	244	0	Good	Good	Good	-
6	Jun-24	165	43	162	144	Good	Good	Good	Good
7	Jul-24	132	44	163	158	Good	Good	Good	Good
8	Aug-24	117	46	169	126	Pretty good	Good	Good	Good
9	Sep-24	123	45	161	201	Good	Good	Good	Good
10	Oct-24	129	40	248	161	Good	Good	Good	Good
11	Nov-24	160	46	173	168	Good	Good	Good	Good
12	Dec-24	156	45	143	218	Good	Good	Good	Good

Source: (Author Data Processing, 2024)

Optimalization of Dock Utilities

Based on the results of BOR utility calculations in 2024, it is also still in need of improvement, especially in March 2024 with the highest number of goods flows and ship visits. The Berth Occupancy Ratio (BOR) in that month reached 85% which is included in the poor category with the utility achievement being 10% above the 70% standard set by the Tanjung Perak Port Authority regulations and UNCTAD standards. Therefore, optimization of stevedoring loading and unloading performance activities is needed to maximize the efficiency of pier use and prevent overutility in the future. The optimization solution provided by making several scenarios by optimizing operational conditions with minimizing Non-Operational Time (NOT) and optimizing facilities in the form of increasing the length of the pier by increasing the number of ship moorings at the International Jamrud Terminal.

1. Scenario 1

Scenario 1 is an optimization solution for operational conditions by reducing Non-Operational Time (NOT). The length of the ship's Berthing Time (BT) is the result of the sum of the Effective Time (ET) of loading and unloading activities, Idle Time (IT), and Non-Operational Time (NOT). Based on the performance data of the International Jamrud Terminal, it is known that work break time, loading and unloading preparations, and ship departure preparations have a very big influence. Therefore, NOT is maximized by reducing work break time, loading and unloading preparation time and ship departure preparation time.

The reduction of work break time has been adjusted to the regulation of Pasal 81 Angka 25 Perppu Cipta Kerja which amends Pasal 79 ayat (2) UU Ketenagakerjaan, there are rules in the provision of workers rest time, namely by changing the work break time which was initially 1 hour to half an hour after working for 4 hours continuously on each shift. In addition, the average time for preparing for loading and unloading and preparing for ship departure was also reduced, which was initially 3 hours and 5 hours consecutively maximized to 2 hours and 3 hours. Thus, the Berthing Time (BT) can be reduced by 8 hours with the average Berthing Time (BT) which was initially 92 hours to 84 hours. Therefore, the calculation of the highest BOR in March 2024 is carried out as follows:

$$BOR = \frac{n\,call \times (LOA + 5) \times BT}{LD \times t(b)} \times 100\,\% = \frac{44 \times (148 + 5) \times 84}{1.010 \times (30 \times 24)} \times 100\,\%$$
$$= 78\,\%$$

Therefore, BOR calculations can be carried out in the January-December 2024 period with a reduction in the NOT time shown in table 14 as follows.

Table 12.
Results of BOR Optimization Scenario 1

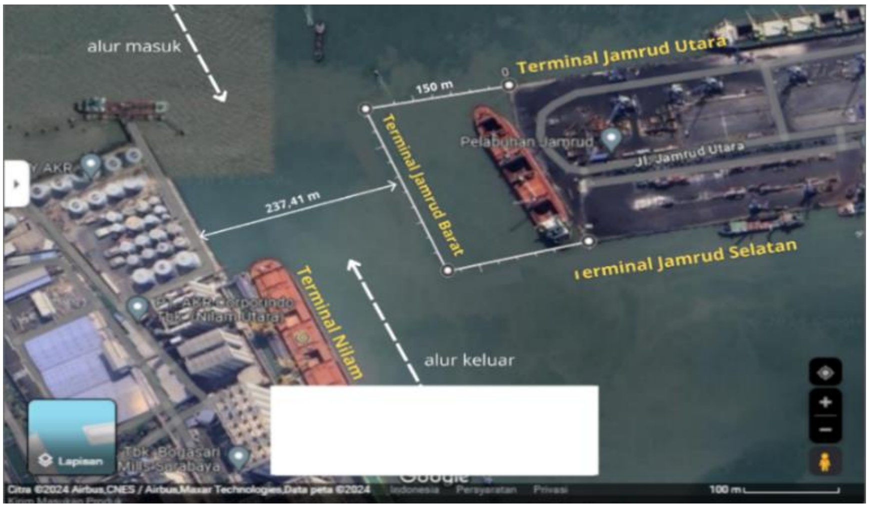
No.	Period	BOR (%)	BOR Assessment
1	Jan-24	69%	Good
2	Feb-24	39%	Good
3	Mar-24	78%	Pretty good
4	Apr-24	49%	Good
5	May-24	39%	Good
6	Jun-24	64%	Good
7	Jul-24	65%	Good
8	Aug-24	60%	Good
9	Sep-24	49%	Good
10	Oct-24	46%	Good
11	Nov-24	37%	Good
12	Dec-24	46%	Good

Source: (Data Processing, 2024)

Based on these calculations, the reduction in Non-Operational Time (NOT) can reduce the highest BOR rate in March 2024 from 85% to 78% so that it can be categorized as quite good with the BOR achievement rate being between 0-10% of the 70% standard set.

2. Scenario 2

Scenario 2 is an optimization solution on the side of terminal facilities by increasing the number of ship moorings so that it requires an increase in the length of the pier. The change in the number of moorings is by increasing the number of ship moorings from 6 moorings to 7 moorings. The addition of the mooring is in line with the increase in the length of the pier which was initially 1,010 meters to 1,155 meters. Therefore, the length of the pier was increased by 150 meters. So that the length of the pier is LD = 1,010 + 150 = 1,160 meters. The following is a visualization of the increase in the length of the International Jamrud Terminal pier in figure 2.



Source: (Google Maps, 2024)

Figure 2. Visualization of Increasing the Length of Pier at The International Jamrud Terminal

Based on the visualization of the addition of the pier for the Jamrud Terminal as shown in figure 2, it can be seen that the additional length of the pier can reduce the ships entrance channel to 237.41 meters, where this channel is the entry and exit route for ships that will enter the waters to dock ships at other terminals. Based on the "*Harbour Approach Channels Design Guidelines*" PIANC Report No. 121, the recommendation for the width of the channel in a port does not have a single definite number that applies to all situations (Pianc 2014). The general description of the recommendations given for the basic width of the channel is based on the width of the largest ship width size, namely:

1. The width of the channel bottom for one direction is generally 3 to 5 times the width of the largest ship.
2. The width of the channel bottom for two directions is generally 6 to 8 times the width of the largest ship.

If the size of the largest ship at the International Jamrud Terminal is 35 meters, then a calculation of the width of the channel can be carried out to estimate the accessibility of the ship, as follows:

Min channel width = 6 x largest vessel width
Min channel width = 6 x 35 m
Min channel width = 210 m < 237 m (Fulfilled)

So based on the calculation results, the minimum channel width is still achieved and the length of the pier can be increased by taking into account the accessibility of ships that will pass through the channel. Then the highest BOR calculation in March 2024 can be carried out as follows.

$$BOR = \frac{n\,call \times (LOA + 5) \times BT}{LD \times t(b)} \times 100\,\% = \frac{44 \times (148 + 5) \times 92}{1.160 \times (30 \times 24)} \times 100\,\% = 74\,\%$$

Therefore, the calculation of BOR can be carried out in the January-December 2024 period with the addition the length of the pier shown in table 15 as follows.

Table 13.
Results of BOR Optimization Scenario 2

No.	Era	BOR (%)	BOR Assessment
1	Jan-24	66%	Good
2	Feb-24	37%	Good
3	Mar-24	74%	Pretty good
4	Apr-24	47%	Good
5	May-24	37%	Good
6	Jun-24	61%	Good
7	Jul-24	62%	Good
8	Aug-24	57%	Good
9	Sep-24	47%	Good
10	Oct-24	44%	Good
11	Nov-24	35%	Good
12	Dec-24	44%	Good

Source: (Author Data Processing, 2024)

Based on these calculations, the additional length of the pier can reduce the highest BOR level in March 2024 from 85% to 74% so that it can be categorized as quite good with the BOR achievement level between 0-10% of the 70% standard set.

3. Scenario 3

Scenario 3 is an optimization solution by combining scenario 1 and scenario 2. In scenario 3, the NOT time was reduced to 84 hours and the length of the pier was also increased to 1,160 meters. Then the calculation of the highest BOR in March 2024 can be carried out as follows.

$$BOR = \frac{n\,call \times (LOA\ +\ 5)\ \times\ BT}{LD \times t(b)} \times\ 100\ \% = \frac{44 \times (148\ +\ 5) \times 84}{1.160 \times (30 \times 24)} \times\ 100\ \% =\ 68\ \%$$

Therefore, the calculation of BOR can be carried out in the January-December 2024 period with a reduction in the NOT time and an increase in the length of the pier shown in table 16.

Table 14.
Results of BOR Optimization Scenario 3

No.	Period	BOR (%)	BOR Assessment
1	Jan-24	60%	Good
2	Feb-24	34%	Good
3	Mar-24	68%	Good
4	Apr-24	43%	Good
5	May-24	34%	Good
6	Jun-24	55%	Good
7	Jul-24	57%	Good
8	Aug-24	52%	Good
9	Sep-24	43%	Good
10	Oct-24	40%	Good
11	Nov-24	32%	Good
12	Dec-24	40%	Good

Source: (Data Processing, 2024)

Based on these calculations, the reduction of the NOT time and the increase in the length of the pier can reduce the highest BOR rate in March 2024 from 85% to 68% so that it can be categorized as good with the BOR achievement below the 70% standard set by the Tanjung Perak Port Authority. This also meets UNCTAD standards, where terminals with 6-10 moorings the recommended standard to be 70%. Thus, it can be concluded that the implementation of scenario 3 is the most optimal optimization solution.

Based on previous research on the Analysis of the Relationship Between Port Facilities and Equipment and Throughput, Case Study: Tanjung Perak Port Surabaya by Nina Oktaviani in 2014, to deal with the long waiting time for ship mooring at Tanjung Perak Port, a solution was carried out in the form of reducing the rest time to 1 hour per *shift (Oktaviani 2014)*. Thus, reducing rest time can solve the problem of *ship overdemand* which has an impact on too long waiting times. Based on the research Analysis of the Performance of Container Terminals in Tanjung Perak Surabaya (Case Study: PT. Surabaya Container Terminal) by (Supriyono 2014), the addition length of the pier and the suppression of Non-Operating Time (NOT) can improve the performance of the dock utility at the Surabaya Container Terminal. Based on this, it can be concluded that the results of the author's research and previous studies have the same results, namely the addition in the length of the pier and the reduction of rest time which affects the maximization of Non-Operating Time (NOT) can reduce the density at International Jamrud Terminal pier.

CONCLUSION

The existing condition of facilities and equipment at the International Jamrud Terminal is classified as good with the achievement of an 80% readiness level of the equipment. The performance of loading and unloading goods on general cargo in October 2024 and in dry bulk cargo in the January-December 2024 period is not good and the highest Berth Occupancy Ratio (BOR) utilization is found in March 2024 with a BOR utilization rate of 85%. The optimization proposal given to improve the level of loading and unloading goods performance on general cargo and dry bulk cargo is carried out by reducing the working gang to 1 working gang, while the optimization solution to reduce the utilization rate of the Berth Occupancy Ratio (BOR) is carried out by applying scenario 3 in the form of reducing ship mooring time and increasing the length of the dock so that it can reach the standard in accordance with Keputusan Kepala Kantor Otoritas Pelabuhan Utama Tanjung Perak No. HK.2.6/01/04/OP.TPr-2020 Tentang Standar Kinerja Pelayanan Operasional Pelabuhan Tanjung Perak.

To prevent the use of piers that are too high in the future, it can be implemented on the operational side and the facility side in the form of reducing ship berthing time and increasing the length of the pier. However, if the terminal wants to apply only on one side, it can use more optimal facility side in the form of increasing the length of the pier. Regarding the decline in the flow of goods and the number of ship visits that are predicted to decrease, so that PT. Pelindo Multi Terminal can provide wider promotions, innovate and improve services that can bring in new customers and expand the network of customers who want to load and unload international non-container goods so as to increase ship visits to International Jamrud Terminal in the future. For further research, it is possible to analyze the use of warehouse facilities and stacking fields, and can analyze the needs of loading and unloading equipment at the International Jamrud Terminal. For forecasting data, you can use data for a longer period of time so that you can use long-term forecasting.

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