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THE APPLICATION OF QUEUING THEORY IN OPTIMIZING SHIP SERVICE PERFORMANCE BY INCREASING THE NUMBER OF PORT DOCK UNITS

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Abstract: The purposes of this study are: (1) To determine the level of service of a terminal case study, KOJA container terminal, experiencing a substantial increase in ship arrivals, (2) To analyze the losses to ships and goods while waiting in queues, and (3) To define the improvement in ship services through the use of additional dock port units. Data used in this study was obtained from KOJA container terminal. The data spanned from January to December 2019 and was analyzed in this study using the M/M/S queuing model. The results showed that the average ship arrival rate was 1.3 per day with a waiting time of 1.21 days. The highest daily rate of ship arrival was 1.7 at which the waiting time was 9.17 days. At a daily ship arrival rate of 1.3, the cost of losses to ship and goods due to queuing was Rp 486,654,212,228. At the highest daily rate of ship arrival of 1.7, the highest cost of losses was Rp. 3,685,490,352,790. The study recommends that KOJA container terminal should increase the number of dock units from 2 to 3 units to decrease the waiting cost for ships and goods.

Keywords: Mooring, Cost, Queuing System, Strategy

1. INTRODUCTION

Transportation is defined as a daily activity of transporting or moving goods or people. This activity is very important not only for Indonesian people but also people worldwide. Transportation is particularly important for Indonesians for some reasons. Since Indonesia geographically is an archipelago consisting of many big and small islands, and in which waters are spread within lakes, rivers, and seas, transportation is really needed either by land, sea or even air to be able to reach everywhere. Indonesia is one of the biggest archipelago

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countries in the world, in which the seas cover about two thirds of the total territory.

Recently, there has been major economy relocation in the world, from the Atlantic to the Asia-Pacific, by which more than 75% of products commodity from Asia pacific is transported through sea transportation. About 45% of them are transported by sea transportation throughout Indonesia islands (Isdiana et al., 2019).

Sea transportation has a great contribution either for Indonesia's national economic or for its districts. The contribution of sea transportation has become even more crucial since it has a lower cost value than land and air transportation (Jusna & Nempung, 2016).

Some facts indicate that our national Maritime sector still requires resolutions to some problems. The main commercial ports performance indicator shows that our ports system is not effective and efficient that they need quality improvement. One of the indicators is the ship mooring occupancy. The average arrival and departure time (turn around) and the working hour as part of the turnaround time percentage is still under the International standard. It shows that ships spend too much on mooring and queuing outside the port (Setiono, 2010).

One of the essential activities in Koja cargo ports is loading and unloading, which are parts of the mooring process that affect the queuing traffic of ships in port. Since numerous ships arrive at Koja terminal port, optimization is urgently needed to minimize the service time of ships loading and unloading which will affect the queuing time.

Based on the background discussed above, the following are this study's research questions;

1. What is the level of service at Koja container port terminal after a substantial increase in ship arraival?

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2. How much are the losses to goods and ships caused by queuing in the terminal?
3. How much is the improvement in ship service by adding additional dock units in the container port terminal of KOJA?

The scope of this study is limited to the data provided for this study and to the container port terminal of KOJA, as a case study. The main focus of this study is the optimization of the ship waiting time and the level of dock utilization. Ship queueing at the port case study was modelled using the M/M/S queue model.

2. THEORETICAL FRAMEWORK

Container Terminal

According to Supriyono (2010), Container Terminal is a place for transporting loads and an interface of land and sea transport. It is a districted area starting from the loading of the container from the ship to its moving to leave the port. There is an enormous number of goods sent by container, and it keeps increasing every year.

Terminal is part of a subsystem of a port which helps the process of sea transport activities. A terminal or port is an interface place where the sea and land transports are met. Ports are responsible for the movement process of a container from land transport to sea transport, and it does conversely. However, the activity is part of the transportation in which the courteous flow of the container will be more dependent on the outside factors, such as;

1. The late ship entering the port is caused by some factors like the ebb tide condition, weather change, failure, a sudden route change, etc.

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2. The other reasons that cause the delay in ship entry to the terminal are accidents, congestion, incomplete document, etc.
3. The large area for stacking the containers.
4. A failure on the crane facility, shuttle truck, container stacker, etc.

According to Usman et al. (2019), queuing is an occurrence which can be found in daily activities, for example, waiting in line in front of a ticket counter for a train or cinema ticket, queuing in toll entrance, banks, supermarket cashiers, and other situations that can often be experienced.

Meanwhile, Aminah et al. (2015) identified the terms of discipline in a queue as a rule in which customers are served. Furthermore, it can also be defined as a service discipline in which the customers' orders are put and served according to the line order. There are four queue discipline forms in line with the arrival order. They are;

1. First Come First Served (FCFS) or First in First out (FIFO) means that a vehicle or a customer which arrives earlier will be served first. This is a common queue discipline that often is used, such as a queue at a cinema ticket counter.
2. Last In Random Order (LCFS) or Last in First out (LIFO) means a vehicle or customer who arrives last will be served first. For example, the queue system at elevator for a similar floor.
3. Service in Random Order (SIRO) or Random Selection for Service (RSS) is a service based on the random chance or that the service will be given randomly. For example, a queue in which the service is given based on a lottery number.

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4. Priority Service (PS) means that a service priority is given to a vehicle or a customer who has higher priority compared to the others, although one who is at the first line is the one who comes the last. This queue discipline usually takes place in a clinic or hospital where the patient who has got the worst illness will get the priority to get the first service.

According to Khabibah (2013), there are four models of basic queuing structure which are commonly happened at all queuing system. They are;

1. Single Channel – Single Phase means there is a single queue only. While Single Channel means there is only one line of service and Single Phase means only one service facility.
2. Single Channel – Multi Phase means that there are more than one service facility for one queue line. The term Multi Phase is defined as two or more services being conducted in order.
3. Multi-Channel –Single Phase or Multi Channel –Single Phase, take place at a time when there are two or more facilities which have a single queue line.
4. Multi-Channel – Multi Phase or a system of Multi-Channel – Multi Phase is a queue system in which there are more than one service provider in every service.

3. RESEARCH METHODOLOGY

The objective of the study is to analyse the queuing pattern of ships at Koja container

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terminal for a year. In order to analyse the queuing pattern of ships, information about the queue criteria, arrival pattern, services and the queue model used are required. After the queuing model is known, the value number of each queuing performance taken will be achieved.

Moreover, the steps taken in this study are;

1. Conducted a library research about the research topic, queuing theory.
2. Collected data samples of the research subject, which is the ships queuing for the loading and unloading service at Koja container port terminal. The data taken here is the data of each ship arrival time followed by the data of the number of ships arriving each day and the number of ships which conducted the loading and unloading process.
3. Decided on a suitable queuing model for the loading and unloading service for a year.
4. Decided the dimension of the system performance, which are the predicted number of ships in the queue (Lq), the number of predicted ships in the system (Ls), the waiting time in queue (Wq) and the waiting time in the system (Ws).

Multi model single channel phase (M/M/S) is a suitable pattern which is used to measure the value of service applied in the queuing system model of container terminal. The patterns are as follow;(Heizer & Render, 2008)

1. 0 probability of person or vehicle in system (no customers in system) (P0)

$$P0 = \frac{1}{[\sum_{n=0}^{M-1} \frac{1}{n!}(\frac{\lambda}{\mu})^{n}] + \frac{1}{M!}(\frac{\lambda}{\mu})^{M} \frac{M\mu}{M\mu-\lambda}} \quad \text{...3.1}$$

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$untuk\ M\mu > \lambda$

2. The level of route utilization (ρ)

$$\rho = \frac{\lambda}{M\mu} \qquad \text{3.2}$$

3. The average number of customers or vehicles in system (Ls).

$$Ls = \frac{\lambda\mu(\frac{\lambda}{\mu})^{M}}{(M-1)!(M\mu-\lambda)^{2}}\,P0 + \frac{\lambda}{\mu} \qquad \text{3.3}$$

4. The average time spent by a customer or a vehicle in a queue or a service time (in system) (Ws).

$$Ws = \frac{\lambda\mu(\frac{\lambda}{\mu})^{M}}{(M-1)!(M\mu-\lambda)^{2}}\,P0 + \frac{\lambda}{\mu}\ atau\ \frac{Ls}{\lambda} \qquad \text{3.4}$$

5. The average number of people or vehicles waiting in queue (Lq)

$$Lq = Ls - \frac{\lambda}{\mu} \qquad \text{3.5}$$

6. The average time spent by a customer or a vehicle (Wq)

$$Wq = Ws - \frac{1}{\mu}\ \ atau\ \frac{Lq}{\lambda} \qquad \text{3.6}$$

Description:

M: The opened route

λ: The average number of arrival per unit.

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μ: The number of served people or vehicles per unit.

P0: The probability is 0 person or vehicle in system.

ρ: The level of route or mooring utilization.

Ls: The average number of customers or vehicles in system.

Ws: The average time spent by a customer or a vehicle in queue or in a service (in system).

Lq: The average number of people or unit of vehicles waiting in line.

Wq: The average time spent by a customer or vehicle waiting in line.

The analysis of the cost of ships in queue

$$DWT \times Wq \times h \quad \text{............} \quad 3.7$$

In which:

h = 1 *USD/DWT/day* 3.8

DWT = the total of DWT ships

ΔWq = the average time spent by ships waiting in line.

The analysis of goods waiting time

$$\frac{\Delta Wq \times b \times c \times d \times e}{j} \text{............} 3.9$$

$$\frac{\Delta WT\ HARI \times TEUs \times \frac{Ton}{Teus} \times \frac{Nilai\ Barang}{Ton} \times BUNGA\ UANG\% \overline{Tahun}}{365\ HARI\ (TAHUN)} \text{............} 4.0$$

In which:

ΔWq = The average difference in time spent by ships waiting in line. (day)

b = Total value TEUs

c = Total Tons/TEUs

d = the goods value per tons

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e = the money interest per year

j = number of days in a year

5. RESULT AND DISCUSSION

The operational activity of Koja container terminal and the aspects of ships visit

The capacity of container ships that visit Koja container terminal achieves 10.000 TEUs. The visits determine the number of mooring docks capable of serving the level of ships arrival so there will not be any queuing in port.

Table 1 The data of container ships arrival in 2019

No	Month	Number of ships (unit)	Container (TEUs)	Total DWT	Service time duration (hour)
1	January	47	75.532	1.477.571	841
2	February	45	64.889	1.373.263	798
3	March	48	75.290	1.389.437	945
4	April	35	79.074	1.244.509	917
5	May	37	80.630	1.238.172	920
6	June	33	59.396	997.385	669
7	July	40	78.170	1.187.770	906
8	August	39	73.494	1.261.080	912
9	September	36	75.535	1.188.157	865
10	October	44	81.866	1.321.050	942
11	November	42	89.376	1.416.551	983
12	December	44	81.063	1.277.541	915
Sum		490	914.315	15.372.486	10613
Average		1,3 (ships)			21,8

Table 1 describes the number of container ship visits in 2019 from January to December from about 490 ships, 914.315 TEUs, 15.372.486 DWT with the average arrival of about 1.3 ships per day, and the service time taken for each ship is 21.8 hours or 0.9 days.

The Queue Analysis

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The queue analysis of Multi-Channel Single Phase or M/M/S is as follows:

If the mooring dock has M=2 moorings, based on the arrival ships data taken from the operational department of Koja container terminal. It was known from the level of service data that μ = 0.9 days is the average time for service for each container, and the average rate of container arrival is $\boldsymbol{\lambda}$ = 1.3 ships per day.

1. The probability of 0 ships in the system (P0) was calculated using Equation (3.1) as 0.16129.

$$P0 = \frac{1}{[\sum_{n=0}^{M-1} \frac{1}{n!} (\frac{\lambda}{\mu})^{n}] + \frac{1}{M!} (\frac{\lambda}{\mu})^{M} \frac{M\mu}{M\mu - \lambda}}$$

$$for\ M\mu > \lambda$$

$$P0 = \frac{1}{[\frac{1}{0!}\left(\frac{1,3}{0,9}\right)^{0} + \frac{1}{1!}\left(\frac{1,3}{0,9}\right)^{1}] + \frac{1}{2!}\left(\frac{1.3}{0,9}\right)^{2} \frac{2\,(0,9)}{2\,(0,9)-1,3}}$$

P0 = 0.16129

1. Equation (3.2) calculates the level of mooring dock utilization of the container terminal as 0.7437 or 74%.

$$\rho = \frac{\lambda}{M\mu}$$

$$\rho = \frac{1,3}{2 \times 0,9}$$

ρ = 0.7437

2. The average number of container ships in the system (Ls) was calculated by Equation (3.3) as 3 container ships

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$$Ls = \frac{\lambda\mu(\frac{\lambda}{\mu})^{M}}{(M-1)!(M\mu-\lambda)^2}\ P_0 + \frac{\lambda}{\mu}$$

$$Ls = \frac{1{,}3\times 0{,}9\ (\frac{1{,}3}{0{,}9})^2}{(2-1)!(2(0{,}9-1{,}3)^2}\ \times 0{,}16129 + \frac{1{,}3}{0{,}9}$$

Ls = 3.01

3. The average time spent by a container ship waiting for a service or having a service in the system (Ws) was calculated by Equation (3.4) as 2.3 days.

$$Ws = \frac{Ls}{\lambda}$$

$$Ws = \frac{3}{1{,}3}$$

Ws = 2,3 days.

4. The average number of container ships waiting in line (Lq) was calculated by Equation (3.5) as 1.5 or 2 ships.

$$Lq = Ls - \frac{\lambda}{\mu}$$

$$Lq = 3 - \frac{1{,}3}{0{,}9}$$

Lq = 1.5

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5. The average time spent by a container ship waiting in line (Wq) was calculated using Equation (3.6) as 1.2 days or 29,07 hours

$Wq = \frac{\text{Lq}}{\lambda}$

$Wq = \frac{1{,}5}{1{,}3}$

Wq = 1.2 days

From the above results, it can be concluded that:

1. From the level of utilization activities of the dock is about 0,72 or 72%.
2. The average number of ships in queue is 1,5 ships or $= 2$ ships.
3. The average number of ships waiting in system is 3 ships.
4. The queuing time needed by a ship is 1,2 days or 29,07 hours.
5. The average time spent by a container ship in system is 2,3 days.

Waiting Time

A comparative investigation was conducted using the M/M/S model to identify the container ship waiting time after increasing the number of mooring docks to 2, as shown in Table 2.

Tabel 2 The performance of ships services with 2 dock moorings

Λ	1,3	1,4	1,5	1,6	1,7
M	0,9	0,9	0,9	0,9	0,9
M	2	2	2	2	2

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P0	0,16	0,13	0,09	0,058	0,02
P	0,72	0,77	0,83	0,88	0,94
Ls	3,01	3,93	5,45	8,47	17,48
Ws	2,32	2,81	3,63	5,29	10,28
Lq	1,57	2,38	3,78	6,69	15,59
Wq	1,21	1,7	2,52	4,18	9,17

Table 2 and Figure 1 show the rate of ship arrival versus the queue waiting time (Wq) at two mooring docks with the increased number of ship arrivals as follows;

1. For the average number of 1.3 ship arrivals per day, the queue waiting time is 1.21 days.
2. For the average number of 1.4 ship arrivals per day, the queue waiting time is 1.7 days.
3. For the average number of 1.5 ship arrivals per day, the queue waiting time is 2.52 days.
4. For the average number of 1.6 hip arrivals per day, the queue waiting time is 9.17 days.

Figure 1 The queue waiting time with 2 and 3 mooring dock units

Cost Analysis

The ships cost during waiting in line.

The ship's cost during waiting in line is calculated from the cost of ship rent with 2 and 3 mooring docks. Using Equation (3.8), the total rental cost of a ship was calculated.

Table 4 The cost of ships rent during waiting time with 2 and 3 dock moorings

(1)	(2)	(4)	(3)	(5)	(6) (3)*(4)*(5)
Λ	M	Wq (day)	DWT	Ships Rent cost 1 USD/DWT/day (Rupiah)	waiting ships cost (Rupiah)
1,3	2	1,21	15.372.486	15.000	279.349.476.774
1,4	2	1,7	15.372.486	15.000	392.318.653.125
1,5	2	2,52	15.372.486	15.000	582.291.136.364

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1,6	2	4,18	15.372.486	15.000	964.548.141.176
1,7	2	9,17	15.372.486	15.000	2.115.546.882.857
1,6	3	0,28	15.372.486	15.000	65.803.959.016
1,7	3	0,39	15.372.486	15.000	90.753.453.158
1,8	3	0,54	15.372.486	15.000	126.522.518.519
1,9	3	0,77	15.372.486	15.000	179.348.807.754
2	3	1,12	15.372.486	15.000	260.460.111.317
2,1	3	1,69	15.372.486	15.000	391.619.332.888
2,2	3	2,68	15.372.486	15.000	619.319.829.467
2,3	3	4,58	15.372.486	15.000	1.057.136.446.249
2,4	3	8,86	15.372.486	15.000	2.043.279.551.402

Table 4 shows that for the 1.3 ship arrival daily rate at two mooring docks in the port, the cost of ship waiting time is about Rp. 279.349.476.774. For the 1.7 ship arrival daily rate at two mooring docks in the port, the cost of ship waiting time has increased dramatically to about Rp. 2.115.546.882.857.

Goods Value and Goods Volume

Table 5 Goods Value in Container in Rupiah/Ton according to (BPS, 2019)

(1)	(2)	(3) (1)/(2)	(4) (3)*15.000
Import Value based on the main port (Value CIF: USD)	**Import Volume based on the main port: netto/ton)**	**Goods value/Ton (USD)**	**Goods Value**
72.020.200.000	37.541.100	1.918	28.770.000

Table 5 calculates the value of 1 ton of goods as 1.918 USD. If it is converted into Rupiah in an assumption of 1 USD is Rp.15.000, the result is that the value of 1 ton of goods is Rp.28.77 million.

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The cost of goods waiting time

Table 7 Waiting goods cost for waiting in line

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) ((3)*(4)*(5)*(6))/365
Λ	**M**	**Wq (Hari)**	**TEUs**	**Ton/TEUs**	**Goods value 1 Ton (juta Rupiah)**	**Bank interest per year**	**Waiting Goods cost (Rupiah)**
1,3	2	1,21	914.315	29,68	28,77	8%	207.304.735.454
1,4	2	1,7	914.315	29,68	28,77	8%	291.138.954.470
1,5	2	2,52	914.315	29,68	28,77	8%	432.117.186.597
1,6	2	4,18	914.315	29,68	28,77	8%	715.789.410.269
1,7	2	9,17	914.315	29,68	28,77	8%	1.569.943.469.933
1,6	3	0,28	914.315	29,68	28,77	8%	48.832.997.553
1,7	3	0,39	914.315	29,68	28,77	8%	67.347.971.493
1,8	3	0,54	914.315	29,68	28,77	8%	93.892.129.433
1,9	3	0,77	914.315	29,68	28,77	8%	133.094.421.994
2	3	1,12	914.315	29,68	28,77	8%	193.286.971.919
2,1	3	1,69	914.315	29,68	28,77	8%	290.619.990.201
2,2	3	2,68	914.315	29,68	28,77	8%	459.596.111.979
2,3	3	4,58	914.315	29,68	28,77	8%	784.499.022.010
2,4	3	8,86	914.315	29,68	28,77	8%	1.516.314.015.523

Table L.7 describes the total TON and TEUs in a container at every country's port, for which the objective is to get the average number of TON/TEUs. By calculating the total cargo volume in TON and dividing it by the container traffic, the result is 29.68 TON/TEUs. (*American Association of Port Authorities*, n.d.)

The total cost of ships waiting time and waiting goods

Table 8 Total cost of waiting in line

1	2	3	4	5	6 (4)*(5)
λ	**M**	**Wq**	**Ships Waiting time Cost**	**Goods waiting time Cost**	**Total cost of waiting time**
1,3	2	1,21	279.349.476.774	207.304.735.454	486.654.212.228
1,4	2	1,7	392.318.653.125	291.138.954.470	683.457.607.595

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1,5	2	2,52	582.291.136.364	432.117.186.597	1.014.408.322.961
1,6	2	4,18	964.548.141.176	715.789.410.269	1.680.337.551.445
1,7	2	9,17	2.115.546.882.857	1.569.943.469.933	3.685.490.352.790
1,6	3	0,28	65.803.959.016	48.832.997.553	114.636.956.569
1,7	3	0,39	90.753.453.158	67.347.971.493	158.101.424.651
1,8	3	0,54	126.522.518.519	93.892.129.433	220.414.647.952
1,9	3	0,77	179.348.807.754	133.094.421.994	312.443.229.748
2	3	1,12	260.460.111.317	193.286.971.919	453.747.083.236
2,1	3	1,69	391.619.332.888	290.619.990.201	682.239.323.089
2,2	3	2,68	619.319.829.467	459.596.111.979	1.078.915.941.446
2,3	3	4,58	1.057.136.446.249	784.499.022.010	1.841.635.468.259
2,4	3	8,86	2.043.279.551.402	1.516.314.015.523	3.559.593.566.925

Table 8 provides the total cost of the ship waiting and the goods waiting at 2 and 3 mooring docks in the port. It is evident that the higher the number of mooring docks, the less the total waiting cost.

The cost of building mooring dock

Table 9 Total cost of building docks

	No	Jobs Detail	Unit	Volume	Unit Price (Million)	Cost (Million)	Note
Land Pavement	1	Reklamasi 1,3 Ha	m²	13000	Rp1,1	Rp14.300	325*40 m²
	2	CY 10 Ha	m²	100000	RP1,9	Rp190.000	
Docks port	1	Dermaga Deep sea port -18m LWS	m²	13000	Rp23	Rp299.000	325*40 m²
Equipment	1	Container Gantry Crane (GC)	Unit	8	Rp105.000	Rp840.000	8 unit CC di dermaga 325m
	2	Transtainer / RTG (5+1 row)	Unit	16	Rp22.500	Rp360.000	CY

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	3	Reach Stacker 40 ton	Unit	8	Rp6.500	Rp52.000	CY
	3	Top Loader	Unit	4	Rp5.000	Rp20.000	CY
	4	Head Truck	Unit	32	Rp800	Rp25.600	CY
	5	Chassis	Unit	64	Rp200	Rp12.800	CY
	6	Forklift 3 ton	Unit	6	Rp300	Rp1.800	CFS 1 & 2
	7	Forklift 10 ton	Unit	2	Rp700	Rp1.400	CY, etc
Total						Rp1.816.900	

(*Indonesian Port Expert Association*, n.d.)

Table 9 calculates the cost of building a mooring dock at a pavement area of 325x40m2 as about Rp 1.816.900.000.000, and the cost of procuring some operational dock equipment. (*Indonesian Port Expert Association*, n.d.)

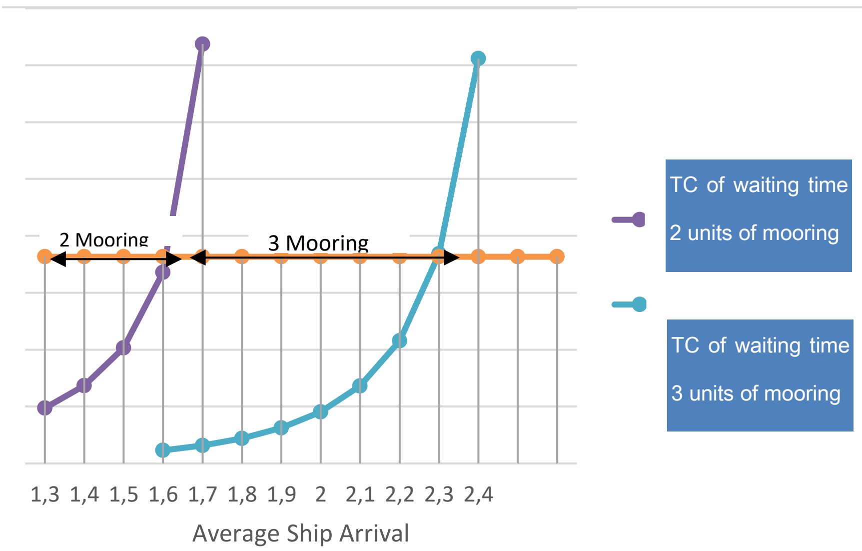

Figure 2 the comparison cost between the ships cost and the dock's building

Figure 2 describes that if the daily rate of ship arrival increased from 1.3 to 1.6, ship waiting time becomes longer, increasing the waiting cost of ships and goods. Therefore, it is advisable that Koja container port terminal increase the number of mooring docks from 2 to 3. This is because the total waiting cost of goods equals the cost of building docks at the

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average rate of ship arrival of 1.6 per day. At the 2.3 daily rate of ship arrival, the terminal port must build an additional dock to add more moorings.

5. CONCLUSION

Based on the analysis of ship queuing at KOJA container terminal of port Tanjung Priuk, it can be concluded that;

Based on the M/M/S queue model results, the level of service of Koja container terminal is worsened by the increase in the daily rate of ship arrival, leading to longer ship waiting times to get services. The waiting time is 1.21 days at the 1.3 daily rate of ship arrival, 1.7 days at the 1.4 daily rate of ship arrival and 2.52 days at the 1.5 daily rate of ship arrival. The waiting time increases dramatically to 4.18 days at the 1.6 daily rate of ship arrival and 9.17 days at the 1.7 daily rate of ship arrival.

1. The queue analysis of Multi-Channel Single Phase or M/M/S, from the level of utilization activities of the dock is about 0,72 or 72%. The average number of ships in queue is 1,5 ships or $= 2$ ships. The average number of ships waiting in system is 3 ships.The queuing time needed by a ship is 1,2 days or 29,07 hours. The average time spent by a container ship in system is 2,3 days.
2. The waiting cost for ships and goods is about Rp486.654.212.228 at the 1.3 daily rate of ship arrival, Rp683.457.607.595 at the 1.4 daily rate of ship arrival and Rp1.014.408.322.961 at the 1.5 daily rate of ship arrival. The waiting cost for ships and goods increases dramatically to RP1.680.337.551.445 at the 1.6 daily rate of ship arrival and Rp3.685.490.352.790 at the 1.7 daily rate of ship arrival.

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3. Koja container terminal is recommended to increase the number of mooring docks from 2 to 3 to decrease the waiting cost for ships and goods. Such a cost reduction is equivalent to the total cost of building the new dock, quantified as Rp1.816.900.000.000, at a daily rate of ship arrival greater than 1.6. At the 2.3 daily rate of ship arrival, the waiting cost for ships and goods is too high to operate the terminal with only two mooring docks, and thus increasing the number of docks to 3 is highly recommended.

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