Transport Safety Improvement : Evaluation of Berthing Facilities and Mooring Patterns at The 16 Ilir River Port in Palembang City

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Abstract. South Sumatra Province has been designated for river transport arrangement in 16 Ilir Palembang City in order to realise safe river transport services through the arrangement of River Port Area 16 Ilir Palembang City. Through the implementation of the acceleration programme (quick wins) at the 16 Ilir River Port of Palembang City aims to improve the service of river facilities and infrastructure as well as the quality of human resources. Currently, the existing mooring system arrangement pattern at the 16 Ilir River Port is not regular and many ships moor outside the dock and it can cause the level of use of the dock to be not optimal. The capacity of the number of ships mooring at each dock is 14 ships, with a perpendicular mooring system of 8 ships and an inclined mooring system of 14 ships with the appropriate type of fender is a minimum of 175x 75 mm dimensioned cylindrical type fenders with a total of 14 fenders (on the dock) and 98 fenders (on the trestle). The research method uses a descriptive quantitative method with a survey approach using numerical calculations as the basis for completing a study. The results obtained (1) the capacity of the number of ships moored at each berth 2A, berth 2B and berth 2C with a longitudinal mooring system is 1 ship, and for berth 1 dock is 3 ships, (2) perpendicular mooring system (at the dock) is 12 ships / dock and oblique mooring system (at the trestel) is 6 ships / dock. (3) the type of fender that is suitable for installation at each berth 1, berth 2A, berth 2B and berth 2C dock is at least a cylinder type fender with dimensions 175x 75 mm (4) the ideal number of fenders to be installed at each berth 1 dock is 60 pieces, berth 2A, berth 2B and berth 2C is 76 pieces.

Keywords: fenders, mooring, transport safety, trestle

1. Introduction

Palembang City is one of the metropolitan cities in Indonesia and has a position as the capital of South Sumatra Province. The high dynamics and activities of Palembang City triggered the rapid development of the city, both the physical development of the city and the activities of the population. The rapid development of the area requires a comprehensive spatial planning as a guideline for land use and develop-

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ment implementation. The development of Palembang City from the past until now is related to the Musi River. Life on the banks of the Musi River characterizes Palembang City. The riverbank area is a potential area whose development becomes very fast. The concentration of activities in the past as commercial areas, residential areas, and public spaces were located on the banks of the river, but over time the Musi River continues to experience changes - changes in dimensions and river flows that tend to shrink.

This year the government is focusing on improving the services of infrastructure, facilities and human resources of River, Lake and Crossing Ports, one of which is in South Sumatra Province in accordance with the Decree of the Minister of Transportation number 1428 of 2018 concerning the Acceleration Program for Improving Infrastructure, Facilities and Human Resources of River, Lake and Crossing Ports in the Provinces of South Sumatra, North Kalimantan, South Sulawesi, East Nusa Tenggara, North Maluku and Papua (quick wins) which was then followed up with the Decree of the Director General of Land Transportation number 1781/AP.005 /DRJD/2019 concerning the Pilot Project Program for Accelerating the Improvement of Infrastructure Services, Facilities and Human Resources on the Musi River in Palembang City, South Sumatra Province.

South Sumatra Province has been designated for the arrangement of river transportation in 16 Ilir Palembang City in order to realize safe river transportation services through the arrangement of the 16 Ilir River Port of Palembang City. The concept of structuring Musi River transportation will apply a modern and safe concept, with the principle of "Ber-7" which includes Ber-Ticket, Ber-Certificate, Ber-Schedule, Ber-Manifest, Ber-Life Jacket, Ber-Asuransi, and Ber-SIB (Sailing Permit). Through the implementation of the acceleration program (quick wins) at the 16 Ilir River Port of Palembang City aims to improve river facilities and infrastructure services and the quality of human resources. On July 15, 2023 the Director General of Land Transportation inaugurated the 16 Ilir River Port and 7 Ulu River Port in Palembang City. Currently the existing mooring system arrangement pattern at the 16 Ilir River Pier is not yet organized and many ships moor outside the pier and it can cause the level of use of the Pier to be not optimal. The position of the ship's berth can affect the safety of passengers and goods when loading and unloading (Adira Balqis, 2021) In this regard, there needs to be follow-up from the local government to improve river transportation services that are smooth, organized, safe, comfortable, and easy to monitor.

2. Literature Study

In terms of hydrological conditions, Palembang City is divided by the Musi River into two large sections called Seberang Ulu and Seberang Ilir. This study was conducted in these two areas because it is suspected that pollution of the Musi River occurs along the River, starting from upstream to downstream. The Musi River is the largest river in Sumatra with a length of 750 km and a depth of up to 25 meters that can be passed by large ships. Musi river flows from major tributaries starting from Jambi and Bengkulu so it is nicknamed as Venice from the East. The Musi River is also called Batanghari.

According to Law Number 17 of 2008 concerning Shipping states that Ships are water vehicles of a certain shape and type that are driven by wind power, mechanical power, other energy, towed or delayed including vehicles with dynamic carrying capacity, vehicles under the water surface, as well as floating devices and floating buildings that do not move. The following are the types of river vessels operating in the South Sumatra Region

Table 1. Types of vessels operating in South Sumatra

Ship Type	Number of Ships			Description
	Sumsel	Palembang City	16 Ilir area	
Jukung	454	200	100	Sumsel
Long Boat	200	95	35	City
Speed Boat	400	100	82	16 Ilir
Ketek	400	202	100	City

Source: BPTD Class II South Sumatra Region,2023

Based on Table 1 above, the types of vessels operating in the 16 Ilir Port Area consist of jukung, long boat, speedboat and ketek. The characteristics of riverboats operating on the Musi River include:

a. Ketek
- Using a clotok engine with a power of <20PK
- Using diesel fuel
- Maximum carrying capacity of 8-10 people
- Has a length of 4-9 meters and a width of 1-1.5 meters

b. Longboat dan Speedboat
- Speedboats have an engine power of 40 PK
- Longboat has an engine power of 200-400 PK
- Has a length of 5.5 meters to 12 meters
- Has a ship width of 1.5- 2.5 meters
- Able to carry 8 to 22 passengers

c. Jukung
- Used for freight transportation
- Has a length of 15-20 meters
- Has a width of 4-6 meters
- Capacity to carry 30-60 tons of goods

According to Regulation of the Minister of Transportation Number 40 of 2022 concerning the Operation of River and Lake Ports, River and Lake ports are ports used to serve river and lake transportation located on rivers and lakes. River and Lake Ports have basic port facilities, one of which is a dock that is used for berthing ships as well as loading and unloading passengers and goods. The following is the productivity of the river port in Palembang City

Table 2. Port Productivity at 35 Ilir River Service Unit Palembang City

Docks	Type of Ship	Arrival			Departure		
		Ship (Unit)	Passenger (People)	Item (Ton)	Ship (Unit)	Passenger (People)	Item (Ton)
16 Ilir	Jukung	5267	-	4480	5267	-	99230
	Speed Boat	3425	14.503	-	3421	14.608	-
	Ketek	2314	6874	-	2314	6.862	-
	TOTAL	**11006**	**21.377**	**4480**	**11002**	**21.470**	**99230**
Under Ampera	Speed Boat	10888	54974	-	10883	54.941	
	Long Boat	8697	140640	-	8697	143.773	-
	Ketek	4302	13.433	-	4304	13303	-
	TOTAL	**23887**	**209047**	**0**	**23884**	**212.017**	**0**
7 Ulu	Jukung	759	3442	821	756	3685	7513
	Speed Boat	-	-	-	-	-	-
	Ketek	3328	10572	-	3326	10607	-
	TOTAL	**4.087**	**14.014**	**821**	**4.082**	**14.292**	**7.513**
TOTAL		**38.980**	**244.438**	**5.301**	**38.968**	**247.779**	**106.743**

Source: BPTD Class II South Sumatra Region, 2023

The pier is a port building used to get and moor ships that carry out loading and unloading of goods and raising and lowering passengers. The shape and dimensions of the pier depend on the type of ship moored at the pier. The dock must be planned in such a way that ships can dock and moor and carry out activities at the Port safely, quickly and smoothly (Triatmojo, Bambang, 2009). The following is the data of the existing docks at the Port of 16 Ilir Palembang City

Table 3. Dock Data at 16 Ilir River Port Palembang City

Name of Docks	Extensive	Capacity	Description
Passenger Dock (Under Ampera)			
- Berth 1	221 m^2	14 mixed units	Longboat and Speed Boat
- Berth 2A	221 m^2	47 mixed units	Longboat and Speed Boat
- Berth 2B	221 m^2		
- Berth 2C	221 m^2		
Departure Passenger Demand	535 m^2	17 mixed units	Longboat and Ketek
Carter Dock (Tourism)	194 m^2	3 mixed units	Longboat and Ketek
Arrival Demaga	391 m^2	12 mixed units	Longboat and Ketek
Jukung Docks	4.316 m^2	34 units	Jukung
Pinisi Docks	1.831 m^2	2 units	Kapal Pinisi

Source: BPTD Class II South Sumatra Region, 2023

Fig. 1. Activities at the Lower Ampera Pier of 16 Ilir River Port

Based on the book Port Planning by Bambang Triatmodjo (2009) the position of the ship docked to the pier, where the ship's cross rope has been tied to the bolder and the activities of loading and unloading passengers and goods.

a. The vertical mooring pattern is where the ship forms a perpendicular row that forms a 900 angle that works on the dock structure in the form of self-load and live load which is transformed evenly, centrally, or as a walking load.
b. The horizontal mooring pattern is where the ships form an angular or oblique row that forms an angle of 450 and the impact force of the ship that the dock must withstand depends on the impact energy absorbed by the fenders installed on the dock.

According to (Adira Balqis, 2021), there are 3 mooring systems or mooring patterns, namely longitudinal, perpendicular, and angled mooring systems..

a. Analysis of mooring capacity of ships with longitudinal mooring systems (180º)

$$L = (2 . a) + (n . LOA) + \{(n - 1) \times b\} \quad (1)$$

Description:
L = Dock length (m)
a = Distance between ship and dock angle (0,5)
LOA= Largest ship length (m)
n =Number of boats that can moor
b =The distance between the ship and the ship is 0,5 m

b. Analysis of mooring capacity with perpendicular mooring system (90°)

$$L = (2 \times a) + (n \times B) + \{(n - 1) \times b\} \quad (2)$$

Description:
L = Dock length (m)
a = Distance between ship and dock angle (0,5)
B = Largest ship width (m)
n = Number of boats that can moor
b = The distance between the ship and the ship is 0,5 m

c. Analisa kapasitastambatkapaldengansistemtambatmenyudut (45º)

$$L = 2\,a + \{\, n . (\cos \alpha . LOA)\} \quad (3)$$

Description:
L = Dock length (m)
a = Distance between ship and dock angle (0,5)
n = Number of boats that can moor
$\propto$ = The angle formed
LOA= Largest ship length (m)

Based on the book Port Planning by Bambang Triatmodjo (2009), the type of fender is determined by the force and energy of the ship's impact on the pier. The ship's impact force that the pier must withstand depends on the ship's impact energy absorbed by the fender system installed at the pier. The amount of impact energy is given by the following formula:

$$E = \frac{WV^2}{2g} C_m C_e C_s C_c \quad (4)$$

Description ;

E = Impact energy (ton meter)
V = The dockside perpendicular component of the ship's speed at impact with the dock (m/d)
W = ship of displasment
g = acceleration of gravity (m^2/d)
C_m= Mass coefficient
C_e = Eccentricity coefficient
C_s = Hardness coefficient (diambil 1)
C_c= Mooring shape coefficient

To determine the maximum distance to be installed on the pier, the calculation is determined by the type of ship that will berth and its deadweight. At this pier the planned fender distance is as follows:

$$L = 2\sqrt{r^2 - (r - h)^2} \tag{5}$$

Description :

L = distance between fenders
r = radius of curvature of the vessel
h = fender height (calculated from the pier floor)

To determine the number of fenders can be calculated using the formula:

$$n = \frac{\text{calculated pier length}}{\text{distance between fenders}} \tag{6}$$

3. Methods

In this study, we used quantitative methods, namely research methods using numerical calculations as the basis for completing a study. The following is a series of research completion:

A. Determination of mooring pattern
To determine the determination of the mooring pattern of the ship, the length of the existing dock is needed at the dock, namely berth 1, berth 2A, berth 2B and berth 2C and the dimensions of the ship that will dock at the dock with longitudinal, perpendicular and angular mooring patterns. Then enter the data into formulas 1, 2 and 3 so as to obtain the number of ships that can dock at the pier, namely berth 1, berth 2A, berth 2B and berth 2C. After the calculation results have been completed, the dock can accommodate ships that dock a number of calculation results.

B. Determination of the ideal Fender Type at the jetty
To determine the right type of fender at the dock, the dimensions of the ship berthing at the dock, namely berth 1, berth 2A, berth 2B and berth 2C, current speed data and ship speed when landing at the dock and dock data are required. Then calculations are carried out using formula 4 by looking for the

amount of impact energy on the pier by entering the calculation data variables and converting to the right fender type table for berth 1, berth 2A, berth 2B and berth 2C. After the calculation results have been completed, the right type of fender is obtained to protect the pier from damage due to ship collisions.

C. Determination of the right number of fenders
To determine the right fender on the pier, it is necessary to have data on the height of the fender and the radius of the fender bend obtained from the type of fend-er calculation results. Then it is done using formula 5 by entering data variables to find the right distance between fenders and then calculating the number of fenders using formula 6 by entering the dock length variable. After the calculation results have been completed, the right number of fenders is obtained to protect the pier from damage due to ship collisions.

4. Results and Discussion

Analysis of ship mooring capacity with an elongated mooring system (180º)

For an elongated mooring system, you can use the left side of the pier at Berth 1, which is 17 meters.

$L = (2 \times a) + (n \times LOA) + \{(n - 1) \times b\}$
$17 = (2 \times 0,5) + (n \times 8) + \{(n - 1) \times 0,5\}$
$17 = 1 + 8\,n + 0,5\,n - 0,5$
$8,5\,n = 16$
$n = 1,8$

From the results of the calculation, the number of ships that can berth with the Berth 1 longitudinal mooring system is 2 ships on the left side of the pier.

For an elongated mooring system, you can use the front side of the pier (pier width) at Berth 1, 2A, Berth 2B and Berth 2C which is 14 meters.

$L = (2 \times a) + (n \times LOA) + \{(n - 1) \times b\}$
$14 = (2 \times 0,5) + (n \times 8) + \{(n - 1) \times 0,5\}$
$14 = 1 + 8\,n + 0,5\,n - 0,5$
$8,5\,n = 13$
$n = 1,5$

From the results of the calculation, it is obtained that the number of ships that can berth with an elongated berth system is 1 ship / pier for each berth 2A, berth 2B and berth 2C, while for Berth 1 the number of ships that can berth is 3 ships.

a. Analysis of mooring capacity with perpendicular mooring system (90°)
From the data for the longitudinal mooring system can use the pier at Berth1, Berth 2A, Berth 2B and Berth 2C which is 17 meters.

$L = (2 \times a) + (n \times B) + \{(n - 1) \times b\}$
$17 = (2 \times 0,5) + (n \times 2) + \{(n - 1) \times 0,5\}$

17 = 1 + 2n + 0,5 n - 0,5

2,5 n= 16,5

n = 6,6

From the results of the calculation, it is obtained that the number of ships that can dock with a perpendicular mooring system is 6 ships / docks with each side of the pier, namely 2 that can be boarded (left and right), then the number of ships that can dock with a perpendicular system is 12 ships for each berth, namely berth 1, berth 2A, berth 2B and berth 2C.

b. Analysis of mooring capacity of ships with angled mooring systems (45°)

From the data for the angled mooring system can use the pier at Berth1, Berth 2A, Berth 2B and Berth 2C which is 17 meters.

L = 2× a + { n × (cos α × LOA)}

17 = 2 × 0,5 + { n . (cos 45 × 8)}

17 = 1 + 0,70 n × 8 n

5,6 n = 16

n = 2,8

From the results of the calculation, the number of ships that can dock with a longitudinal mooring system is 3 ships / pier, the number of ships that can dock with an angled mooring system is 6 ships for each berth, namely berth 1, berth 2A, berth 2B and berth 2C.

c. Fender Type Analysis

Then the largest ship displacement can be calculated:

$\Delta = L.B.d.cb.\rho$ = 12 m x 3 m x 1 m x 0,70 x 1 ton/m^3

= 25,2 ton

The weight of the ship in its full state is:

W = Ship displacement + Load Capacity

= 25,2 ton + 5 ton

= 30,2 ton

To find the ship's speed at berth, from the table it is known that the DWT of the ship is 30.2 tons (including DWT up to 500) from the direction parallel to the pier. Then the ship speed

= V x Sin 90^0

=0,25 m/s x 1

= 0,25 m/s

To find the impact energy caused by the ship with the above formula, it is necessary to know several components. Here's how to find some of the components that affect the ship's impact power:

1) Search C_m

$$\mathrm{Cm} = 1 + \frac{\pi}{2\ \mathrm{Cb}} \times \frac{\mathrm{d}}{\mathrm{B}}$$

$$\mathrm{Cm} = 1 + \frac{3{,}14}{2(0{,}70)} \times \frac{1}{3}$$

Cm = 1,68

2) Search C_e

$$Ce = \frac{1}{1+(\frac{l}{r})^2}$$

L = ¼ LOA

= ¼ (12 m)

L = 3 m

R = 0,205 LOA

= 0,205 (12 m)

R = 2,67 m

so,

$$Ce = \frac{1}{1+(\frac{1}{2,67})^2}$$

C_e =1,25

The amount of impact energy of the ship is:

$$E = \frac{WV^2}{2g} C_m C_e C_s C_c$$

$$E = \frac{30,2 \text{ x } 0,25^2}{2\ (9,8)} \text{ x } 1,68 \text{ x } 1,25 \text{x } 1 \text{ x } 1$$

$$E = \frac{1,89}{19,6} \text{x } 1,68 \text{x } 1,25$$

E = 0,20 ton meter

So the force that will be received due to the impact of the ship on the pier is 0.20 ton meters. and which can be absorbed by the fender is 0.10 ton meters Based on the cylinder fender table, the type of cylinder fender with dimensions 175x 75 mm.

d. Analysis of Number and Spacing of fenders

The formula used to determine the maximum distance between fenders is:

$$\frac{r}{loa} = 0,205$$

r = Loa x 0,205

r = 12 m x 0,205 = 2,46 m

h = fender height = 0,14 m

Then the distance between fenders can be calculated using the formula:

$$L = 2\sqrt{r^2 - (r-h)^2}$$

$$= 2\sqrt{2,46^2 - (2,46 - 0,14)^2}$$

L= 1,7 m

So the distance between fenders is 1,7 m.

The number of fenders installed on each side of the pier length is

$$= \frac{\text{Dock Length}}{\text{Distance between fenders}}$$

$$= \frac{17\ m}{1,7\ m}$$

= 10 fender

So the number of fenders needed for each side of the berth length 1, berth 2A, berth 2B and berth 2C is 20 fenders..

The number of fenders installed on each side of the pier width is

$$= \frac{\text{lebar dermaga}}{\text{jarak antar fender}}$$

$$= \frac{14\ m}{1{,}7\ \ m}$$

= 8,2 fender≈ 8 fender

So the fenders installed on the width of berth 2A, berth 2B and berth 2C are 56 fenders and berth 1 is 40 fenders.

5. Conclusion

Based on the results of the analysis, the following conclusions are obtained : the capacity of the number of ships moored at each berth 2A, berth 2B and berth 2C with a longitudinal mooring system is 1 ship, and for berth 1 is 3 ships for the straight mooring system (at the dock), there are 12 ships / docks and the oblique mooring system (on the trestle), there are 6 ships / docks, the type of fender that is suitable for installation on each berth 1, berth 2A, berth 2B and berth 2C is at least a cylinder type fender with dimensions of 175x 75 mm and the ideal number of fenders to be installed at each berth 1 pier is 60 pieces, berth 2A, berth 2B and berth 2C is 76 pieces.

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