Clustering ferry ports class-I based on the ferry ro-ro tonnages and main dimensions

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Abstract. Capacity constraint of port for Ferry Port Class I is not clearly stated in the Indonesian National Order of Port Affairs. It only said that ferry ship to be serviced is ships with more than 1000 gross tonnages (GTs). The word more than 1000 GTs is unclear as there are ships with up to 12500 GTs to be serviced in this port. This research introduces cluster of Ferry Port Class I. Ship main dimension and tonnage of sample ships is being used as a basis for the port clustering. The result shows that Ferry Port Class I should be divided into three main Ferry Port Classes I (Class I_A, Class I_B and Class I_C). This new cluster of Ferry Port Class I can be used as a reference in updating the rules regarding ferry port class and as a reference in the design of ferry port main facilities.

1 Introduction

Ferry transport service is one of the three types of transport services in Indonesian waters. As an extension of main road transport service, ferry transport service must be developed to strengthen the intra and inter connectivity of Indonesian regions especially for inter islands transport service. Transport services in a ferry transport service route is organized by supply some ferry ro ro ships to be operated regularly and continuously. Since the types of ship to carry passengers and vehicles to service the route is ferry ro ro ship, then the ferry port facilities are equipped with some facilities to support ro-ro (roll on – roll off) loading and unloading activities of passengers, vehicles and their cargos.

Ferry ports can be classified into three ferry port classes which are Ferry Port Class I, Ferry Port Class II and Ferry Port Class III [1]. The consideration for classification of ferry ports is mainly based on the port capacities which are expressed in ship gross tonnage (GT). Ferry port capacities for each class then can be divided into Class I for ship with tonnage more than 1000 GTs, Class II for ship with tonnage between 500 GTs and 1000 GTs and Class III for ship with tonnage less than 500 GTs.

There are four ferry transport services in Indonesia which can be categorized as the main routes i.e, Merak-Bahauheni, Ketapang-Gilimanuk, Padangbai-Lembar and Bajoe-Kolaka. Although all of these ferry ports can be categorized as Ferry Port Class I but the capacities of the port on each ferry port is different each other. The maximum gross

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tonnage of ferry ro ro which service those routes is different as well. The maximum gross tonnage which service the route is represents the port capacity of each port in each route. The capacity of each port from the biggest capacity is Merak-Bakauheni ferry port with 12498 GTs of capacity, Ketapang-Gilimanuk ferry port with 876 GTs of capacity, Padangbai-Lembar ferry port with 2916 GTs capacity, and Bajoe-Kolaka ferry port with 1504 GTs as the smallest capacity [2].

2 Research Methodology

Based on the previous descriptions, the stages for further classification of the Ferry Port Class I can be divided into first, the determination of the sample ship main dimension. The ship main dimension information will be used to determine the ship sample tonnage. Finally, the classification of the Ferry Port Class I will be determined. This classification will be based on the ship main dimension and ship tonnage.

2.1 The determination of the ship sample main dimension

The ship sample main dimension will be determined with the following steps.

a. The determination of the ship sample length between perpendicular (L_{BP}) and ship breadth (B) can be done using equation (1) and (2) [3].

For L_{BP} determination:

$$L_{BP} = (\Sigma\,(C_{vi}\,L_{vi}) + D_{fa}\,(C_v - 1))\,/\,L_r \quad (1)$$

Where:

C_{vi} = the number of columns for each type of vehicles
Lvi = the length of each vehicle types
Dfa = the distance between two vehicles
Cv = the number of vehicles columns
Lr = ratio between the length of vehicles area (Lv) with the length of the ship length between perpendicular (L_{BP}). Lr is determined to be 0.9.

For B determination

$$B = \Sigma(R_{vi}\,B_{vi}) + D_s\,(R_v - 1)) + 2\,D_{vp} + 2\,D_{ps} \quad (2)$$

Where:

Rvi = the number of rows for each type of vehicles
Bvi = the breadth of each vehicle types
Ds = the side distance between two vehicles
Rv = the number of vehicles rows
Dvp = the distance between the outer vehicles side on the outer row with the ship inner partition.
Dps = the distance between the ship inner partition with the ship breadth side.

According to the technical guidance on the minimum service requirements of ship on the river, lakes and between islands [4], the value of Dfa, Ds, and Dvp, can be determined to be 0.3 meter, 0.6 meter, and 0.6 meter respectively. Meanwhile, the value of *Dps* is determined to be 1.5 meter. The above mentioned vehicles for the determination of ship sample length and breadth is from vehicles in group IV, which is cars with the car length up to 5 meters [5] and breadth is 2.1 meter [6].

The determination of a ship length combination is based on a ratio between ship length between perpendicular (L_{BP}) and ship breadth (B) in which for ferry ro-ro in Indonesia is in a range of 3.0 and 6.5. The biggest L_{BP} value is not exceeding the biggest ship ferry ro-ro length in Indonesia which is 131.67 m. The minimum ship sample length and breadth was determined for the ship sample tonnage which is more than 1000 GT.

b. Ship height determination can be done using the equation (3). In this equation, the ship height (H) dimension is the ratio between ship length between perpendicular (L_{BP}) and ship height (H) as a function of a ratio between ship length between perpendicular (L_{BP}) and ship breadth (B).

$$LBP/H = 5.2483\ (LBP/\ B)^{\ 0.6792}\ ;\ S\ = \pm\ 1.592 \tag{3}$$

Based on the deviation standard (S) in equation (3), there are three alternatives of ship height (H) which is determined for each ship sample length-breadth variation. They are the highest height (H_H), intermediate height (H_M) and the lowest height (H_L).

c. The determination of ship draught (T) can be done by calculating the ratio between ship breadth (B) and ship draught (T) (*B/T*) as a function of the ratio between ship breadth (B) and ship height (H) (*B/H*) as can be seen in the following equation (4).

$$B/T = 1.1765\ (B/H)^{1.1617}\ ;\ S\ = \pm\ 0.569 \tag{4}$$

Based on the deviation standard (S) in equation (4), there are three alternatives of ship draught (T) which is determined for each ship sample breadth-height variation. They are the highest draught (T_H), intermediate draught (T_M) and the lowest draught (T_L)

2.2 The determination of the ship sample tonnages

After the ship main dimension has been determined, ship gross tonnage (GT) of each ship sample can be calculated with the following steps:

a. The calculation of ship volume tonnage (VT) which consist of ship hull volume (VH) and ship superstructure volume (VS) can be done using the equation (5), (6) and (7) below [7]:

$$VH = 1.04\ LBP\ B\ T\ CB\ (1.25\ H/T - 0.25) \tag{5}$$

$$VS = LBP\ B\ (0.0036\ LBP\ B\ + 0.6687) \tag{6}$$

$$VT = VH\ + VS \tag{7}$$

Note: the value of ship block coefficient (CB) which being used in the calculation of the ship hull volume is 0.60.

b. The calculation of the ship gross tonnage (GT) using equation (8) as in the following [5]:

$$GT = (0.2 + 0.02\ \log10\ VT)\ VT \tag{8}$$

Ship tonnage volume (VT) in this calculation is according to the ship tonnage volume in equation (7).

2.3 Further classification of the ferry port class I

After the The last stages for the classification of the Ferry Port Class I is the determination of cluster of the Ferry Port Class I. This classification is based on the group of the ship sample main dimension and ship sample tonnages.

a. Ship sample classification which is based on the ship main dimension and ship tonnage were conducted through the determination of interval class as a result of the ship length between perpendicular (L_{BP}) with the ship breadth (B) (L_{BP} x B) using the equation 9, 10 and 11. The result of multiplication between ship breadth and ship length (L_{BP} x B) can be used as a representation of ship dimension and tonnage because ship height (H) was calculate as a function of ship length (L_{BP}) and ship breadth (B) (refer to equation 3), while ship draught (T) was calculated as a function of ship breadth (B) and ship height (H) (refer to equation 4).

$$r = db - dk \tag{9}$$

$$k = 1 + 3,3 \log n \tag{10}$$

$$p = r / k \tag{11}$$

where:
r = interval
db = the biggest data value
dk = the smallest data value.
k = number of class
n = number of data
p = length of the class interval.

b. Identification of the biggest ship sample main dimension and tonnage on each interval class.
c. Determining the cluster of the Ferry Port Class I by minimizing similarity and maximizing the capacity differences for ships service between the port classes.

3 Result and analysis

3.1 The main dimension of the sample ships

By using equation (1) and (2), the ship sample length between perpendicular (LBP) and the ship sample breadth (B) can be calculated and the result can be seen in Table 1. There are 14 groups or series of the ship lengths (with code Ln), and 5 groups or series of the ship breadth (Bn) in the table. The number on the ship length code and the number of the ship breadth code are both show the number of columns and rows of vehicles in group IV which can be loaded on the ship sample.

Tabel 1. Ship sample length and ship sample breadth

Length		Breadth (B_n) (m)				
Code (L_n)	L_{BP} (m)	B_3	B_4	B_5	B_6	B_7
L_9	52,667		14.400	17.100		
L_{10}	58,556		14.400	17.100		
L_{11}	64,444	11.700	14.400	17.100	19.800	
L_{12}	70,333	11.700	14.400	17.100	19.800	22.500
L_{13}	76,222	11.700	14.400	17.100	19.800	22.500
L_{14}	82,111		14.400	17.100	19.800	22.500
L_{15}	88,000		14.400	17.100	19.800	22.500
L_{16}	93,889		14.400	17.100	19.800	22.500
L_{17}	99,778			17.100	19.800	22.500
L_{18}	105,667			17.100	19.800	22.500
L_{19}	111,556			17.100	19.800	22.500
L_{20}	117,444				19.800	22.500
L_{21}	123,333				19.800	22.500
L_{22}	129,222				19.800	22.500

The number of the ship sample in this analysis and being the basic for the determination of ship tonnage is 405 ships sample. These ships can be categorized as follows. The number of ship in the category of ship length and ship breadth which is the ship with a variation of different ship length and breadth is 45 ships sample. On each ship length and breadth variation, there is an addition of 3 ships height variation (calculated using equation 3). Hence the total of the sample ships with this additional criterion is 135 ships sample. With the addition of criterion of the last ship draught variation to the previous criteria (calculated using equation 4), then the total ship samples will be 405.

In Figure 1, it shows the result of the calculation to determine ship sample height (H) and draught (T) as described previously. However, the figures only show the intermediate height (HM) as well as intermediate draught (TM). The highest and the lowest value in the interval are not shown.

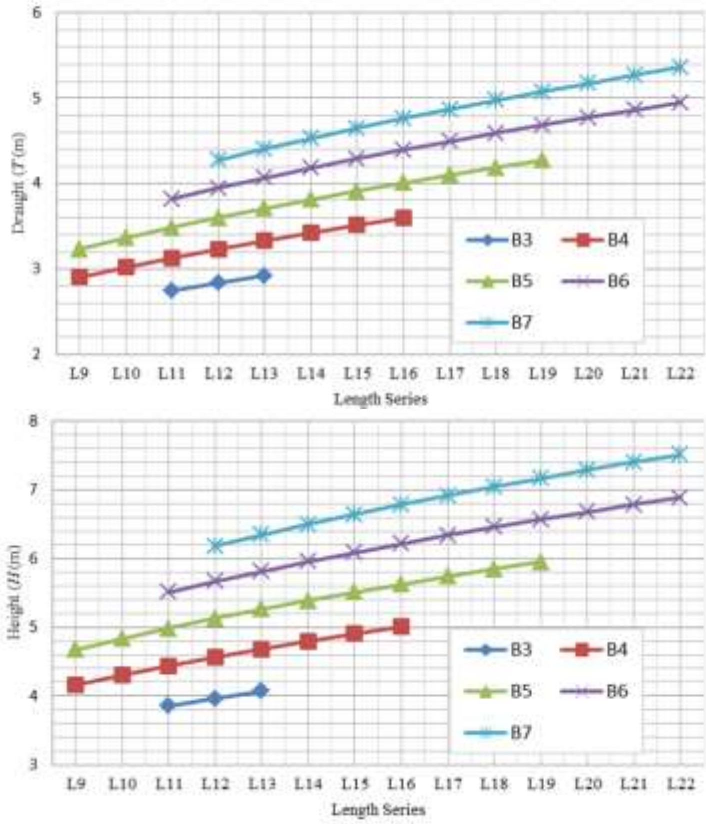

Figure 1. Ship sample height and draught (H vs L and H vs D)

4 Ship sample tonnages

As have been mention earlier, there are 405 variations of ship sample main dimension are being used in this calculation. Gross tonnage for each ship sample is calculated using equation 5, 6 and 7. Interval for ship sample gross tonnage is 1.169 GTs with LBP = 64.444 meter, B = 11.700 meters, H = 3,508 meters, T = 2,785 meters for the smallest ship sample gross tonnage up to the biggest gross tonnage of 14,351 GTs of the ship sample with its main dimension of LBP = 129.222 meters, B = 22.500 meters, H = 8.314 meters, T = 5.249 meters. Figure 2 shows a graph for the result of ship sample gross tonnage calculation.

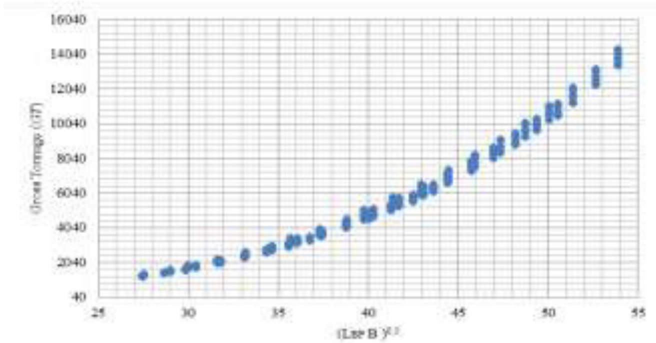

Figure 2. Ship sample gross tonnage

In figure 2, a ship with its length and breadth is more than other ship is tending to have more gross tonnage value. But some ships with the same length and breadth have different gross tonnage value as they are have different height. The same thing happens for the sample ships with the same length and breadth but different draught. They are having different tonnages as well. For the ships with the same length, breadth and height, the smaller the ship draught, the biggest gross tonnage it has.

5 Clustering the ferry port class I

For the 45 variations of ship sample length (LBP) and breadth (B) which being used in this research (Table 1), the biggest and smallest result of multiplication between ship length and breadth is 2908 m2 and 754 m2. By applying equation 9, 10 and 11, the number of ship sample main dimension can be divided into 6 classes with the length of the class interval is 359 m2. Based on these interval classes, the ship sample main dimension with the biggest tonnage on each interval classes are shown in Table 2 below.

Tabel 2. Ship sample main dimension with the biggest tonnage in each interval class

Interval class	Ship main dimension				Ship tonnage (GT)
	L_{BP} (m)	B (m)	H (m)	T (m)	
A	129,222	22,500	8,314	5,249	14351
B	111,556	22,500	8,021	5,062	11105
C	93,889	22,500	7,703	4,858	8260
D	105,667	17,100	6,436	4,064	5982
E	70,333	19,800	6,540	4,121	3996
F	64.444	17.100	5.722	3.606	2629

In Table II, it can be seen that a ship with bigger tonnage does not have bigger ship main dimension elements to compare with a ship with smaller tonnage. As in interval class C, the ship with the biggest tonnage has smaller ship length than the ship length of a ship with the biggest tonnage in interval class D. Further, ship with the biggest tonnage in interval class D has smaller ship breadth, height and draught than the ship breadth, height and draught of a ship with the biggest tonnage in interval class E.

As a consequence, the design of main facilities of port area cannot be based on the ship main dimension with the biggest tonnage. Hence, there must be clarity on the biggest ship main dimension elements of a number of ship main dimensions in each interval class. Tonnage and ship main dimension elements in each interval class are shown in Table 3.

Table 3. Tonnage and ship main dimension elements in each interval class

Interval Class	Biggest Tonnage GT)	The biggest ship main dimension elements			
		L_{BP} (m)	B (m)	H (m)	T (m)
A	14351	129.222	22.500	8.314	7.083
B	11105	129.222	22.500	8.021	7.746
C	8260	111.556	22.500	7.703	6.338
D	5982	105.667	22.500	7.357	6.007
E	3996	93.889	19.800	6.540	5.358
F	2629	82.111	17.100	5.772	4.708

Though there are 6 interval classes or 6 levels of ship tonnage, ship length and breadth level are only 5 and 3 levels (Table 3). Based on the clustering principle which is minimizing similarities and maximizing the differences between classes, cluster of ship main dimension and tonnage for the determination of cluster Ferry Port Class I is divided into three clusters as can be seen in Table 4. Tonnage and ship main dimension in interval class A, B, C and D are combined and become one cluster of port (Port Cluster IA) for servicing ships in tonnage range of 4400 GTs up to 14351 GTs while in interval classes E and F, they are become Port Cluster IB and IC respectively and servicing ships in tonnage range 3000 GTs up to 4400 GTs for port class IB and 1000 GTs up to 3000 GTs for port class IC.

Table 4. Cluster of ferry port class I

Port Cluster	Ship tonnage (GT)	The biggest ship main dimension elements			
		LBP (m)	*B* (m)	*H* (m)	*T* (m)
I_A	$4400<GT\leq14351$	129.222	22.500	8.314	7.083
I_B	$3000<GT\leq 4400$	93.889	19.800	6.540	5.358
I_C	$1000<GT\leq 3000$	88.000	17.100	5.835	4.834

The range of ship main dimension and tonnage in Table 4 become the capacity constraints of servicing ships on each cluster in Ferry Port Class I. The constraints are based on following reasons:

a. On the ships groups with the ship breadth of 17.1 meters, there are ship with the tonnage of 3030 GTs (or 3000 for simplification). Up to this tonnage, the biggest ship length to be serviced is 88.0 meters.

b. On the ships groups with the ship breadth of 19.8 meters, there are ship with the tonnage of 4389 GTs (or 4400 for simplification). Up to this tonnage, the biggest ship length to be serviced is 93.889 meters.

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6 Discussion

Based on the basis for determination of water area need of Ferry Port [8], the water area of ferry port was determined as a function of ship main dimension. Elements of ship main dimension which will be the variables for the port water main facilities consist of:

a. Ship length (L) which being variable for port length, area for ship (length and breadth) berthing, diameter of turning basin and diameter of dock basin.

b. Ship breadth (B) which being variable for the width of water ways

c. Ship draught (D) which being variable for the depth of the port basin

As being described in the previous section, the range of the ship main dimension with tonnage between 1.169 GT and 14.351 GT is big. It covers ship length (LBP) from 64.444 m up to 129.222 m, ship breadth (B) from 11.70 m up to 8.314 m and ship draught from 2.785 m up to 5.249 m. As a consequence, Ferry Port Class I should be divided into three clusters as shown in Tabel 4.

The division of the Ferry Port Class I into three sub classes is needed to strengthen the regulation on the determination of the capacity of the ferry port main facilities for ship service. The port capacity constraint which is in ship tonnage (GT) must be clarified with the biggest ship main dimension elements consist of ship length, ship breadth, ship height and ship draught that can be serviced. The ship main dimension elements as referred is not the biggest ship main dimension with the biggest tonnage in each cluster but instead, it is the biggest ship main dimension elements from a number of ship main dimension variation in each cluster.

Further, clustering the Ferry Port Class I into three sub classes is needed in order to strengthen the regulation on the placement of ship in a ferry route which is suitable to its Ferry Port Class. On the other hand, the clarity of cluster to be serviced and ferry port capacity will increase the smooth and safety operation of ship in the ferry port area. The determination of the pier length, the area for ship berthing, diameter of turning basin and diameter of dock basin which is based on the biggest ship length overall (LOA) to be serviced is to guarantee the smooth and safety operation for berthing process and maneuverability of other ship. The width of water ways in turn must be based on the biggest ship breadth to be serviced as well in order to anticipate the sea current driving force and sea wave on ship at the time of ship entering and exiting ferry port area. In the end, the depth of the port basin must be based on the biggest ship draught to be serviced to prevent ship to run aground in the ferry port area.

7 Conclusion

This research introduces a new cluster for Ferry Port Class I. In the Decree of Minister of Transportation of Republic of Indonesia [1], the Ferry Port Class I is for ship with tonnage more than 1000 GTs. The word “more than 1000 GTs” is unclear as in fact there is a big range of ferry ro-ro with more than 1000 GTs from 1000 GT itself up to 12500 GTs. Hence there is no clear and specific classification for Ferry Port Class I.

In this research, the further classification of the Ferry Port Class I have been analyzed and introduced. This classification has clarified on what ship tonnage and what ship main dimension which can be put on service on certain ferry route which appropriate with the ferry port capacity. The analysis is based on the ship main dimension and tonnages. The result of the analysis shows that the Ferry Port Class I must be divided into three clusters which is:

a. Ferry port class IA for servicing ship with the capacity up to 14351 GTs and with the ship length (LBP) is 129.222 meters or with the ship breadth (B) is 22.5 meters.

b. Ferry port class IB for servicing ship with the capacity up to 4400 GTs with the ship length (LBP) is 93.889 meters or with the ship breadth (B) is 19.8 meters.

c. Ferry port class IA for servicing ship with the capacity up to 3000 GTs with the ship length (LBP) is 88.0 meters or with the ship breadth (B) is 17.1 meters.

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