INTERNATIONAL JOURNAL OF METACENTRE
MARITIME APPLICATION, TECHNOLOGY, ENGINEERING, AND TRANSPORTATION
http://ijm-nasp.unhas.ac.id. eISSN : 2809-8307

# Clustering of Ferry Trajectory Distance Based on Port Class and Ship Technical Specification

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*Received: 20/10/2024*
*Revised: 05/11/2024*
*Accepted: 06/12/2024*
*Published:31/12/2024*

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**Abstract**

A ferry route connects two ports, between a port and a terminal, and between two terminals at a certain distance. A certain distance is the distance of the ferry trajectory that allows for round-trip ferry services. Ships departing from the port of origin to the port of destination can return to the port of origin on the same day. The trajectory distance ($D_{FT}$ (nautical miles) was once grouped into 8 (eight) distance groups, each connected to the gross tonnage cluster of the ship, namely: the shortest (Group 1): $D_{FT} \leq 1.0$ nautical miles; and the farthest (group 8): $D_{FT} >$ 120 nautical miles. The Indonesian Government implemented these distance groups in the period 2003 - 2019. Ferry trajectory distance groups are needed to calculate transportation rates and place ships on a ferry route. This study is intended to evaluate and determine the distance group by the characteristics of ferry transportation services, namely shuttle services. The grouping is based on the class of ferry ports and the technical specifications of ferry ships. The results of this study indicate that one of the eight ferry trajectory distance groups implemented, group 2.4, does not match the characteristics of ferry transportation services (shuttle services). In the distance group, $40.1 \leq F_{TD}$ (nautical miles) $\leq 80.0$, ferrying or frequency of ship operations is only 1 trip/day. The distance group 2.4 must be changed to $40.9 \leq D_{FT}$ (nautical miles) $\leq 70.9$ to achieve a ferrying frequency of 2 trips/day. Through this study, eight groups of clustering of ferry trajectory distance are proposed to be implemented by the Indonesian Government. The shortest and longest distance groups, are the first distance group (group of 3.1): $D_{FT}$ (nautical miles) $\leq 2.3$; and the eighth distance group (group of 1.2): $101.9 \leq D_{FT}$ (nautical miles) $\leq 165.2$. Research on passenger perceptions of safety and comfort in relation to the duration of the voyage and the dimensions of the ship needs to be carried out to ensure the grouping of ferry trajectory distances orientation are towards service quality.

Keywords: Clustering; Ferry transportation; Ferry trajectory distance

## 1. Introduction

A ferry trajectory is a connection between two ports, between a port and a terminal, and between two ferry terminals at a certain distance ([1]; Article 22, paragraph (2), letter c). What "certain distance" means is that not all land separated by water is connected by ferry transportation. Instead, the connected land is a development of the road network and/or railway network separated by waters while still fulfilling the characteristics of ferry transportation ([1], Explanation of Article 22).

The abstracted definition of the term certain distance in relation to the characteristics of ferry transportation is the ferry trajectory distance (hereinafter referred to as the trajectory distance) that allows for round-trip ferry transportation services. Ships departing from the port of origin to the port of destination can return to the port of origin on the same day. Thus, a certain distance can be defined as a route distance that allows for ferry transportation services of at least one round-trip crossing in one day.

The trajectory distance was previously grouped into 8 (eight) groups (see Table 1), each associated with a gross tonnage cluster of the ship ([2]; Article 11, Paragraph 1, letter b). The trajectory distance grouping is intended to calculate ferry service rates as a function of the ship's operating costs. The Minister of Transportation's Decree [2] came into effect in 2023 but has been revoked and declared null and void after being updated in 2019 [([3], Article 22). The trajectory distance grouping is not regulated in the new Minister of Transportation's Regulation [3].

**Tabel 1**. Group of Ferry trajectory distance

| Number | Group of Ferry Trajectory Distance (JL(mil)) | Ship's Gross Tonnage (GT) |
|---|---|---|
| 1 | JL ≤ 1,0 | 300 |
| 2 | 1,1≤ JL ≤ 6,0 | 400 |
| 3 | 6,1≤ JL ≤ 10,0 | 500 |
| 4 | 10,1≤ JL ≤ 20,0 | 600 |
| 5 | 20.1≤ JL ≤ 40,0 | 750 |
| 6 | 40,1≤ JL ≤ 80,0 | 1000 |
| 7 | 80,1≤ JL ≤ 120,0 | 1200 |
| 8 | JL ≥ 120,0 | 1500 |

Source: [2], Article 11, Paragraph 1, letter b.

A group of trajectory distances is needed to calculate transportation rates and place ships on the ferry route. The basic principle of ship placement on the ferry route is the suitability between the ships' number and loading capacity with the daily transport capacity requirements. The maximum ferry frequency that can be achieved in a day (*F*max (trips/day)) multiplied by the average cumulative loading capacity of the number of ships operated is what is meant by daily transport capacity. Fmax can be calculated as multiplying the number of crossing lanes by the frequency of ship operations achieved on each ferry lane (*F*S (trips/day)).

The frequency of ship operations referred to above can be determined as a number rounded down from the result of dividing the port operating time ($P_{\mathrm{OT}}$ (hours/day)) by the ship operating time per trip (SOT (hours/trip)). The ship operating time per trip includes two parts of the ship operating time, namely, the ship operating time in port (PT (hours/trip)), and the ship's time on the voyage ($S_{\mathrm{T}}$ (hours/trip)). The ship's time on a voyage can be calculated by dividing the trajectory distance ($D_{\mathrm{FT}}$ (miles)) by the ship's speed ($V$ (knots)).

The ship's speed is an element of the minimum service requirements for ferry transportation. In accordance with the provisions ([4], Article 7), the minimum service requirements for ship speed consist of:

1) Medium-speed ships must be able to serve ferry transportation at a maximum speed of up to 18 knots.
2) High-speed ships must be able to serve ferries at speeds above 18 knots.

The required ship speed on a ferry trajectory depends on the needs of the operating pattern (ship loading capacity, ferry frequency) according to the demand for transportation services and the trajectory distance. However, the maximum speed that can be achieved by each ship depends on its length. According to Asri ([8], page 647), the maximum recommended speed for ro-ro ferries can be determined as a function of the length ($L_{\mathrm{BP}}$) and the ratio of length to width ($L_{\mathrm{BP}}/B$).

Ship speed requirements are derived from passenger comfort requirements in relation to sailing duration. According to the provisions ([4], Article 3), the minimum service requirements for passenger comfort based on sailing duration consist of four categories, which are:

1) Category 1: sailing duration up to 4 hours, consisting of sailing duration up to 1.5 hours, and above 1.5 hours up to 4 hours.
2) Category 2: sailing duration above 4 hours to 8 hours.
3) Category 3: sailing duration above 8 hours to 12 hours.
4) Category 4: sailing duration above 12 hours.

Ship speed is an implication of the correspondence between the voyage's duration and the route's distance. However, the ship speed and duration of the voyage required for each group of trajectory distance have not been explicitly stated in the minimum service requirements for ferry transportation. Suppose the number of requests for transportation services is the same. In that case, a longer trajectory distance requires a ship with a higher speed or a larger load capacity than a shorter trajectory.

By the distance of the ferry trajectory, the ship speed is a variable of the maximum voyage duration and service frequency that can be achieved per unit of service time. The highest optimal ship speed is a function of the proportion of the length and breadth of the ship. The size of the port waters' main facilities limits the ship's length and breadth.

This study is intended to determine the group of ferry trajectory distances. The grouping is based on the ferry port class and the ferry ships' technical specifications.

By its provisions ([5], Article 22, Paragraphs (2), (3), and (4)), the class of ferry ports is divided into three classes with criteria and indicators as in Table 2 below.

**Tabel 2.** Classification of ferry ports

| Number | Criteria | Unit | Ferry Port | | |
|---|---|---|---|---|---|
| | | | **Class- I** | **Class-II** | **Class-III** |
| 1 | Volume of loads | | | | |
| | a. Passenger | person/day | >2000 | 1000 - 2000 | < 1000 |
| | b. Vehicle | car/day | >500 | 250 - 500 | < 250 |
| 2 | Frequency of ferrying | Trip/day | < 12 | 6 - 12 | <6 |
| 3 | Harbour pier capacity | Ship’s tonnage (GT) | >1000 | 500 - 1000 | < 500 |
| 4 | Port operation time | hours/day | > 12 | 6 - 12 | < 6 |

Source: [5]; Article 22, Paragraph (1), (2), (3), and (4)

The range of harbour pier capacity in each port class in ship tonnage (GT) in Table 2 shows that the cluster and range of ship's dimension and speeds that can be placed in each ferry route must be adjusted to the port class. In relation to the technical specifications of ships, clusters and ranges of crossing distances that match the port class need to be clarified. Each group of crossing distances is stated with three parameters: the range of trajectory distances, ferrying frequency, and the range of ship operating speeds. The ferrying frequency is determined to be at least 2 (two) trips per day. The ship's operating speed is determined to be a maximum of 18 knots. The highest speed limit is based on the Technical Instructions for Minimum Service Requirements for River, Lake, and Ferry Transportation ([4], Article 7, Paragraph 2, Letter b), namely: medium-speed ships must be able to serve routes/crossings with a maximum speed of up to 18 knots.

## 2. Methods

As explained in the introduction, this study is intended to determine the groups of ferry trajectory distances. The grouping is based on the class of ferry ports and the technical specifications of the ferry ships. With this objective, the first step taken is to determine the technical specifications of a number of sample ships. The next step is to evaluate and determine the proposed ferry trajectory distance groups.

### 2.1. Determination of Technical Specifications of Sample Ships

The sample ship referred to here is a ro-ro ferry-type ship. The technical specifications of the sample ship include main dimensions, speed, tonnage, and load capacity. The main dimensions (width (B), the length between perpendicular lines hereinafter referred to as ship length ($L_{BP}$), height (H), and draft (T) of each sample ship are determined successively using equations (1) to (5) as follows ([8], page 645):

$$B = \Sigma(Rvi\ Bvi) + Ds\ (Rv - 1)) + 2\ Dvp + 2\ Dps \tag{1}$$

$$L_{BP} = (\Sigma(Cvi\ Lvi) + Dfa\ (Cv - 1))/Lr \tag{2}$$

$$L_{BP}/B = 0.594\ L_{BP}^{0.4832} \quad ; \pm\ 0.512 \tag{3}$$

$$L_{BP}/H = 5.2463\ (L_{BP}/B)^{0.6792} \quad ; \pm\ 1.592 \tag{4}$$

$$B/T = 1.1765\ (B/H)1.1617 \quad ; \pm\ 0.569 \tag{5}$$

Rvi, Bvi, Ds, Rv, Dvp, and Dps in equation (1), respectively, are the number of rows for each vehicle class, the width of each vehicle class, the distance between the sides of the vehicle; Ds = 0.6 m., the number of rows of vehicles, the distance between the sides of the vehicles on the outermost row and the wall or side barrier of the ship; Dsvp = 0.6 m., and the distance between the wall or side barrier of the ship and the edge of the deck of the ship; Dps = 1.5 m.

Cvi, Lvi, Dfa, Cv, and Lr in equation (2), respectively, are the number of columns for each vehicle class, the length of the vehicle for each class, the distance between the rear faces of the vehicles; Dfa = 0.3 m., the number of vehicle columns, and the ratio between the length of the vehicle area ($L_{VA}$) and the length of the ship ($L_{BP}$); Lr = 0.9.

In ferry transportation services, loads in the form of vehicles are divided into nine groups, namely: group I is a vehicle in the form of a bicycle), groups II and III are vehicles in the form of a motorbike, while groups IV to IX are vehicles in the form of a car. The standard length and width of cars for each vehicle class are listed in Table 3 below.

**Tabel 3**. Size Standard of vehicle in the form of a car for ferry transportation

| Groups | Vehicle (car) size | | Vehicle Unit Index (VUI) |
|---|---|---|---|
| | **Length[1)] ($L_V$(m))** | **Breadth[2)] ($B_V$(m))** | |
| IV | $5,00 \leq L_V \leq 7,00$ | 2,10 | 1.00 |
| V | $5,00 \leq L_V \leq 7,00$ | 2,10 | 1.40 |
| VI | $7,00 \leq L_V \leq 10,00$ | 2,50 | 2.38 |
| VII | $10,00 \leq L_V \leq 12,00$ | 2,50 | 2,86 |
| VIII | $12,00 \leq L_V \leq 16,00$ | 2,50 | 3,81 |
| IX | $L_V \geq 16,00$ | 2,50 | 4,76 |

Sources: [1)] = [3]. Appendix I, pages 1 -2; [2)] = [6]. Article 5, Paragraph 3

According to the Length ($L_{BP}$) and the ratio of length to width ($L_{BP}$/B), the speed of each sample ships is determined by equation (6) ([8], page 647):

$$V_{max} = 0{,}729\ [\{g\ (L_{BP} + L_{BP}/B)\}0{,}5]^{\ 0{,}7295} \tag{6}$$

The block coefficient ($C_B$) of each sample ship was determined using equation (7) ([7], page 26):

$$C_B = 1.09 - 1{,}68\ Fn\ ;\ Fn = V/(g\ L_{BP})^{0.5} \tag{7}$$

Fn, V, and g in equation (7) are the Froude number, speed (m/s), and gravitational force of 9.81 m/s$^2$, respectively.

The hull volume ($V_H$), superstructure and deck houses volume ($V_S$), tonnage volume (VT), and gross tonnage (GT) of each sample ship are determined successively using equations (8) to (11) ([9], page 107):

$$V_H = 1.04\ L_{BP}\ B\ T\ C_B\ (\ 1.25\ \frac{H}{T}\ -\ 0.25\ ) \tag{8}$$

$$V_S = L_{BP}\ B\ (0.0036 L_{BP}\ B + 0.6687 \tag{9}$$

$$V_T = V_H = V_S \tag{10}$$

$$GT = K_1\ V_T\ ;\ K_1 = 0.2 + 0.02\ \log 10\ V_T \tag{11}$$

The length and breadth of the ro-ro ferry are variables of its vehicles loading capacity. For vehicles in the form of cars that can be placed on the main deck of the ship, the loading capacity ($L_C$) of each sample ship in vehicle unit (VU) is calculated using equation (12). One vehicle unit in question is one class IV vehicle, namely a car with the following dimensions: length ($L_V$) = 5.00 m. and breadth ($B_V$) = 2.1 m.

$$L_C = \Sigma\{(NVi)\ (VUIi)\} \tag{12}$$

$NV_i$ and $VUI_i$ in equation (12) are the number of vehicles for each group, and the vehicle unit index for each group, as listed in column 4 in Table 3.

## 2.2. Evaluation of the ferry trajectory distance group

The ferry trajectory distance groups that have been implemented are listed in Table 1. These route distance groups will be evaluated based on the frequency of crossings that can be achieved according to the port's operating time and the speed of ships that can be placed on a ferry trajectory according to its port class. Adjustments to the trajectory distance group will be made in accordance with adjustments to the ferrying frequency by considering the characteristics of the crossing transportation operations, namely shuttle services or ship operating frequency of at least 1 round trip per day.

Port operating time ($P_{OT}$ (hours/day)) and frequency of ship ferrying or departures at each port ($F_D$ (trips/day)) are two of the five criteria for determining the class of ferry ports (see Table 2, rows 2 and 4).

Based on the two criteria for determining the class of ferry ports, the service or operation time of ships at the port ($P_T$ (hours/trip)) is determined as the result of dividing the port operating time ($P_{OT}$) by the frequency of ship departures at the port ($F_D$), which is 1 hour/trip. The operating time of ships at the port includes the time for ship maneuvering in and out of the mooring, and the berthing time to carry out loading and unloading activities.

The operating time of ships per trip ($S_{OT}$ (hours/trip)) is the sum of the operating time of ships at the port ($P_T$) and the sailing time ($S_T$ (hours/trip)). The duration of the ship on the voyage is the distance of the ferry trajectory ($D_{FT}$ (miles)) divided by the speed of the ship ($V$ (knots)). Thus, the operating time of ships per trip is formulated as in equation (13) below.

$$S_{OT} = P_T + \frac{D_{FT}}{V} \quad (13)$$

The symbols of $S_{OT}$, $P_T$, $D_{FT}$, and $V$ in equation (13) are ship operating time per trip (hours/trip), ship time in port (hours/trip), trajectory distance (nautical miles), and ship speed (knots), respectively.

According to the port operating time ($P_{OT}$ (hours/day)) and ship operating time per trip ($S_{OT}$ (hours/trip)), the maximum operating frequency that can be achieved by a ship ($F_S$ (trips/day)) can be determined by the following equation (14).

$$F_S = int \frac{P_{OT}}{P_T + \frac{D_{FT}}{V}} \quad (14)$$

The symbol $F_S$ in equation (14) is the maximum operating frequency that can be achieved by a ship operated full time ($F_S$ (trips/day)). The symbols $P_{OT}$, $P_T$, $D_{FT}$, and $V$ in equation (14) are the same as in equation (13).

If the ship's operating frequency has been determined, the trajectory distance that can be achieved according to the ship's speed and port operating time can be determined using Equation 15.

$$D_{FT} = V \left( \frac{P_{OT}}{F_S} - P_T \right) \quad (15)$$

The symbols in equation (15) are the same as those in equation (14).

## 3. Result and Discussion

### 3.1. Technical Specification of Sample Ships

In sequence, the technical specifications of the sample ships determined in this study are the main dimensions, speed, gross tonnage, and load capacity. The first element of the main dimensions that is determined is the breadth (B) using equation (1). By the variation of the vehicle row arrangement, the breadth of the sample ships is determined by as many as six groups as listed in Table 4.

**Table 4**. Breadth group of ship sample

| Breadth Group | Number of car rows | | Breadth (B(m)) |
|---|---|---|---|
| | $C_{2.1}$ | $C_{2.5}$ | |
| $B_1$ | 2 | - | 9,00 |
| $B_2$ | - | 2 | 9.80 |
| $B_3$ | 3 | - | 11.70 |
| $B_4$ | 2 | 1 | 12.10 |
| $B_5$ | - | 3 | 12.90 |
| $B_6$ | 4 | - | 14.40 |

$C_{2.1}$ = The car with breadth of 2,10 m, $C_{2.5}$ = The car with breadth of 2,50 m.

By applying equation (2), the variation of length ($L_{BP}$) in each width group (B) is determined within the limits of the $L_{BP}$/B ratio by equation (3). Furthermore, the height (H) and draft (T) are determined by the approach in accordance with equations (4) and (5).

As a function of length ($L_{BP}$) and the ratio of length to width ($L_{BP}$/B), the speed for each sample ship is determined using equation (6). The block coefficient (CB) as a function of length (LBP) and speed (V) is determined using equation (7).

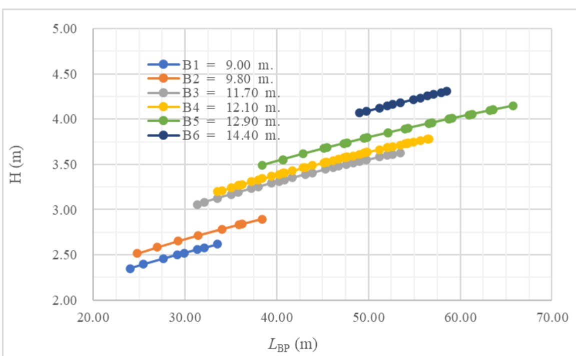
According to the main dimensions and block coefficients, the gross tonnage (GT) of all sample ships is calculated using equations (8) to (11). The load capacity of each sample ship is determined using equation (12).

An overview of the calculation of the technical specifications of the sample ships, as explained in the previous four paragraphs is listed in Table 5 below.

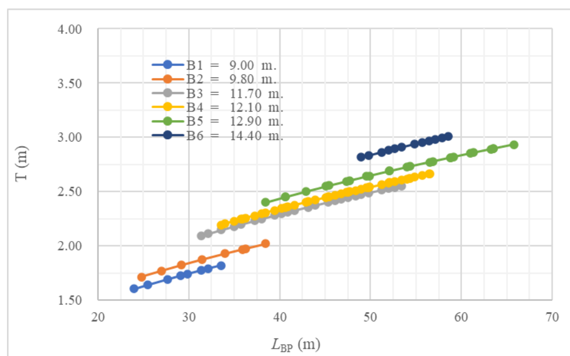
**Tabel 5**. Technical specifications of the sample ship

| Number | Technical Specification | Breadth Groups | | | | | |
|---|---|---|---|---|---|---|---|
| | | ***B*₁= 9.00 m** | ***B*₂= 9.80 m** | ***B*₃= 11.70 m** | ***B*₄= 12.10 m** | ***B*₅= 12,90 m** | ***B*₆= 14,40 m** |
| 1 | Number of dimensions variations | 8 | 8 | 24 | 42 | 24 | 12 |
| 2 | Main dimensions: | | | | | | |
| | a. $L_{BP}$ (m) | 24,00 - 33.56 | 24.78 – 38.44 | 31.33 – 53.44 | 33.56 – 56.56 | 38.44 – 65.78 | 49,00 – 58,56 |
| | *b. H (m)* | 2.35 – 2.62 | 2.52 – 2.90 | 3.06 – 3.63 | 3.20 – 3.78 | 3.49 – 4.15 | 4.07 – 4.30 |
| | *c. T (m)* | 1.61 – 1.82 | 1.72 – 2.02 | 2.09 – 2.55 | 2.19 – 2.66 | 2.40 – 2.93 | 2.82 – 3.01 |
| 3 | *V* (knots) | 10.79 – 12.20 | 10.89 – 12.78 | 11.80 – 14.33 | 12.08 – 14.62 | 12.68 – 15.42 | 13.81 – 14.74 |
| 4 | Gross Tonnage (GT) | 150 - 255 | 182 – 368 | 360 – 869 | 426 - 1016 | 597 - 11477 | 1093 – 1480 |
| 5 | Load capacity (LC ($V_U$) | 5,60 – 9,60 | 6.24 – 11.43 | 8.20 – 25.00 | 16.74 – 29.80 | 18.57 – 36.67 | 31,60 - 38 |

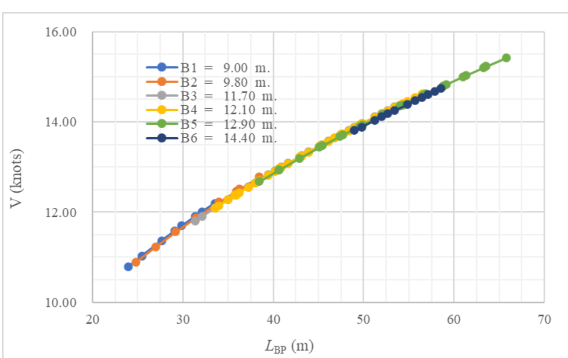
As an explanation, the technical specifications of the sample ship described above are illustrated in Figure 1 below.



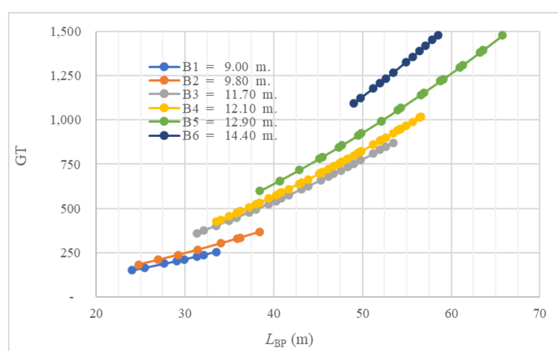

1.1. Height ( *H*) = f ($L_{BP}$)



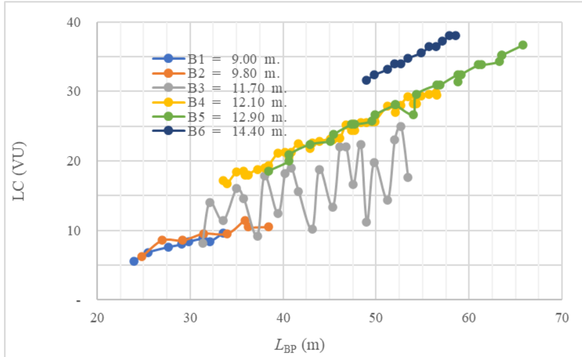

1.2. Draught ( *T*) = f ($L_{BP}$)




1.3. Speed ( *V*) = f ($L_{BP}$)



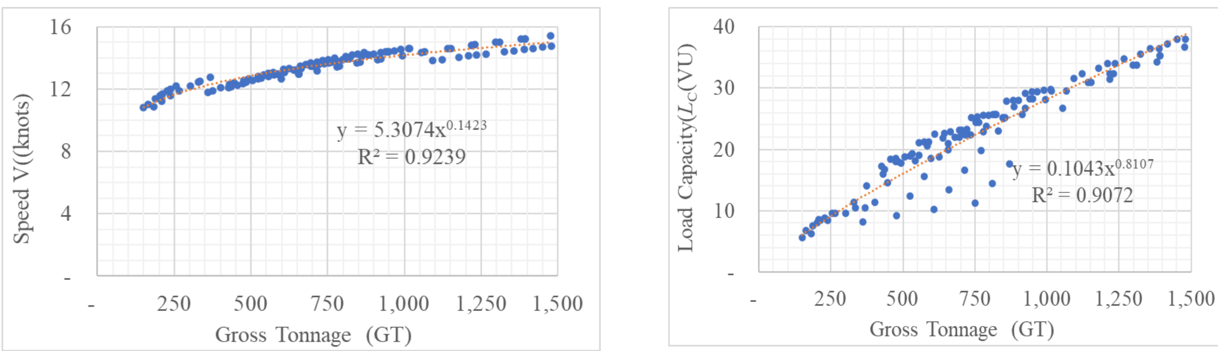

1.4. Gross Tonnage ( GT) = f ($L_{BP}$)




1.5. Load Capacity ( $L_C$) = f ($L_{BP}$)

**Figure 1**. Sample ships technical specification

Gross tonnage is a function of the principal dimensions ($L_{BP}$, $B$, $H$, $T$) and block coefficient ($C_B$). Speed ($V$) is determined as a function of length ($L_{BP}$) and the ratio of length to width ($L_{BP}$/B). Load capacity ($L_C$) is determined as a function of length ($L_{BP}$) and Breadth (B). Thus, it is logical to express the speed and load capacity as a function of gross tonnage (see Figure 2).




2.1. $V$ = f (GT) 2.2. $L_C$ = f (GT)

**Figure 2**. Correlation of gross tonnage (GT) with speed ($V$) and load capacity ($L_{C.}$)

As can be seen in Figure 2, the correlation between speed ($V$) and load capacity ($L_C$) with gross tonnage (GT) can each be expressed by a mathematical model as in the following equations (16) and (17).

$$V = 5{,}3074\ GT^{0.1423} \tag{16}$$

$$L_C = 0.1043\ GT^{0.8107} \tag{17}$$

The two equations above, (16) and (17), are used to determine the speed ($V$ (knot) and loading capacity ($L_C$ (VU)) of each sample ship.

The total variation of main dimensions of the sample ships is 118. If they are grouped according to the port capacity for ship services in each class of ferry port, the details of the number and range of tonnage, speed, and loading capacity of the sample ships are shown in Table 6 below.

**Table 6.** Technical specifications of sample Ships are detailed according to port class and gross tonnage cluster.

| No. | Technical specifications | Ferry Port Class | | |
|---|---|---|---|---|
| | | III | II | I |
| 1 | Cluster of Ship Tonnage (GT) | Cluster - III; GT ≤ 500 | Cluster - II; 500 ≤ GT ≤ 1000 | Cluster - I; GT > 1000 |
| 3 | Number of sample ships | 29 | 62 | 27 |
| 4 | Main dimension: | | | |
| | *a.* $L_{BP}$ (m) | 24.00 – 38.44 | 37.22 – 55. 67 | 49.00 – 65.78 |
| | *b. B (m)* | 9.00 – 12.10 | 11.70 – 12.90 | 12.10 -14.40 |
| | *c. H (m)* | 2.35 – 3.28 | 3.29 – 3.85 | 3.78 – 4.30 |
| | *d. T (m)* | 1.61 – 2.26 | 2.28 – 2.69 | 2.66 - 3.01 |
| 5 | *Speed (V* (knots) | 10.79 – 12.78 | 12.55 – 14.53 | 13.81 – 15.42 |
| 4 | Gross Toonage (GT) | 150 - 493 | 506 - 994 | 1013 – 1480 |
| 5 | Load capacity (LC ($C_U$) | 5.60 – 18.58 | 10.20 – 29.60 | 26.67 – 38.00 |

## 3.2. Evaluation of the ferry trajectory distance group

As an evaluation of the crossing distance groups that had been implemented (see Table 1), the ferrying frequency that can be achieved in each crossing distance group is calculated as listed in column 6 in Table 7 below.

**Table 7**. Evaluation of the cross-crossing distance groups that have been implemented

| Ferry Port Class | Number | Ferry Trajectory Distance Groups | Ferries Tonnage | Ferries Speed | Port Operation Times | Ferrying Frequencies |
|---|---|---|---|---|---|---|
| | | $F_{TD}$ (sea miles) | (GT) | $V_{max}$ (knots) | POT (hours/day) | *F* (trip/day) |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| III | 3.1 | $F_{TD} \leq 1{,}0$ | 300 | 11.95 | 6 | 5 |
| | 3.2 | $1{,}1 \leq F_{TD} \leq 6{,}0$ | 400 | 12.45 | 6 | 4 |
| II | 2.1 | $6{,}1 \leq F_{TD} \leq 10{,}0$ | 500 | 12.85 | 12 | 6 |
| | 2.2 | $10{,}1 \leq F_{TD} \leq 20{,}0$ | 600 | 13.19 | 12 | 4 |
| | 2.3 | $20.1 \leq F_{TD} \leq 40{,}0$ | 750 | 13.61 | 12 | 3 |
| | 2.4 | $40{,}1 \leq F_{TD} \leq 80{,}0$ | 1000 | 14.18 | 12 | 1 |
| I | 1.1 | $80{,}1 \leq F_{TD} \leq 120{,}0$ | 1200 | 14.56 | 24 | 2 |
| | 1.2 | $F_{TD} \geq 120{,}0$ | 1500 | 14.03 | 24 | 2 |

## 3.3. Proposed Clustering of Ferry Trajectory Distance

One of the eight groups of ferry trajectory distances implemented, group 2.4, does not match the characteristics of ferry transportation services (shuttle services). In this distance group, 40.1 ≤ DFT ≤ 80.0, the frequency of ferrying or ship operations achieved is only one trip/day (See Table 7, row number 2.4).

Based on the frequency of ferrying that can be achieved by each ship operated on a ferry route of at least two trips/day, the ferry trajectory distance groups are proposed as listed in column number 8 in Table 8 below. The shortest and longest distance groups in this table are distance group 3.1: $D_{FT} \leq 2.3$ miles; and distance group 1.2: 101.9 miles $\leq D_{FT} \leq$ 165.2 miles. In particular, the distance group 2.4 significantly changes from $40.1 \leq D^{FT} \leq 80.0$ to 40.9 ≤ DFT ≤ 70.9 so the crossing frequency achievement becomes two trips/day. The distance groups are calculated using equation (15).

**Table 8**. Proposal of ferry trajectory distance group

| Ferry Port Class | Number | Port Operation Times | Ferries Specification | | Ferrying Frequencies | Sailing Time | Ferrry Trajectory Distance Groups |
|---|---|---|---|---|---|---|---|
| | | **POT (hours/day)** | **Tonnage (GT)** | **Speed ($V_{max}$(knots))** | ***F* (trip/day)** | **ST (hour/trip)** | **$D_{Ft}$ (sea miles)** |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| III | 3.1 | 6 | 300 | 11.95 | 5 | 0,2 | $D_{FT} \leq 2,3$ |
| | 3.2 | 6 | 400 | 12.45 | 4 | 0.5 | $2.4 \leq D_{FT} \leq 6,2$ |
| II | 2.1 | 12 | 500 | 12.85 | 5 | 1.4 | $6.3 \leq D_{FT} \leq 17,9$ |
| | 2.2 | 12 | 600 | 13.19 | 4 | 2 | $18.0 \leq D_{FT} \leq 26,3$ |
| | 2.3 | 12 | 750 | 13.61 | 3 | 3 | $26.4 \leq D_{FT} \leq 40,8$ |
| | 2.4 | 12 | 1000 | 14.18 | 2 | 5 | $40,9 \leq D_{FT} \leq 70,9$ |
| I | 1.1 | 24 | 1200 | 14.56 | 3 | 7 | $71.0 \leq D_{FT} \leq 101,8$ |
| | 1.2 | 24 | 1500 | *15.03* | 2 | 11 | $101.9 \leq D_{FT} \leq 165.2$ |

Based on the ship speed associated with each distance group, the duration of the voyage to cover the distance is listed in column (7) in Table 8. The categories of duration of the voyage (ST (hours/trip)) for each route distance group are as follows:

1) Trajectory distance group on ferry routes with class III ports; Category 1a (ST ≤ 1.5 hours).
2) Trajectory distance group on ferry routes with class II ports; Category 1.a (ST ≤ 1.5 hours; Category 1.b (1.5 ≤ ST(hours) ≤ 4.0); and Category 2 (4 ≤ ST(hours) ≤ 8.0).
3) Trajectory distance group on ferry routes with class I ports; Category 2 (4.0 ≤ ST(hours) ≤ 8.0); and Category 3 (8 ≤ ST(hours) ≤ 12.0).

The duration of the voyage is a function of the trajectory distance and the speed of the ship. The speed and tonnage of the ship are derivative functions of its dimensions. The voyage duration and the ship's dimensions affect the passengers' sense on safety and comfort. In this regard, research is needed to understand the perception of passengers on safety and comfort during the duration of the voyage and the ship's dimensions. That research is required to ensure the grouping of ferry trajectory distances is based on service quality orientation.

## 4. Conclusions

This study introduces the evaluation results of the trajectory distance groups that were once implemented by the Indonesian Government (2003-2019) as follows:

1) One of the eight crossing distance groups that were once implemented, group 2.4, does not match the characteristics of the crossing transportation service (shuttle service). In this distance group, $40.1 \leq D_{FT}$ (nautical miles) ≤ 80.0, the ferrying frequency or ship operation frequency that can be achieved is only one trip/day. The distance group 2.4 must be changed to $40.9 \leq D_{FT}$ (nautical miles) ≤ 70.9 to achieve a ferrying frequency of two trips/day.
2) Propose to the Indonesian Government to implement the eight of ferry trajectory distance groups, as listed in column 8 in Table 8. The shortest and farthest distance groups are: the first distance group (3.1): $D_{FT}$ (nautical miles) ≤ 2.3; and the eighth distance group: $101.9 \leq D_{FT}$ (nautical miles) ≤ 165.2, respectively.
3) Research into passenger perceptions on safety and comfort during the duration of the voyage and the ship's dimensions needs to be carried out to ensure the grouping of ferry trajectory distances is based on service quality orientation.

## References

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[3] Regulation of the Minister of Transportation of the Republic of Indonesia Number 66 of 2019 Concerning the Mechanism for Determining and Formulating the Calculation of Ferry Transportation Tariffs.

[4] Decree of the Director General of Land Transportation Number AP.005/3/13/DPRD/94 Concerning Technical Instructions for Minimum Service Requirements for River, Lake, and Ferry Transportation.

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