Lane Meters Correlation Analysis towards the Main Dimensions of Ro-ro Ships under 2000 GT

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Keywords: Ferry Ro-Ro, Gross Tonnage, Lane Meter, Pearson Correlation, Regression.

Abstract: The size of ro-ro ships in Indonesia was clustered based on Gross Tonnage (GT). Other units, Lane Meter (LM) can better describe the possible condition of vehicle loads on ships. LM naturally represents the combined length of the entire lane in meters that can be used to load vehicles. This study aims to discover the correlation between the value of LM and GT on ro-ro ships' main dimensions. It proposes mathematical models that can properly estimate the LOA, LPP, and B of the ro-ro ship using LM as an input value. To measure the value of LM, this study used 94 ro-ro ships with sizes below 2000 GT and 90 m length. Correlation test was done through Pearson correlation method by performing several linear regression and ANOVA tests. LM provides a better correlation than GT on LOA, LPP, and B with a correlation value (r) ≥ 0.75. Visible results of the linear regression of LM properly showed strong determinant value, with value of R Square ≥ 0.75. Meanwhile standard ANOVA tests of LM performed on LOA, LPP, and B positively have significance values (sig. ≤ 0.05).

1 INTRODUCTION

Size of Ro-ro ships in Indonesia was clustered with Gross Tonnage or GT. Gross tonnage is the calculation of the volume of all space located below the deck of the ship. It includes the volume of the enclosed space located above the deck with the contents of the room along with all the enclosed spaces located above the top deck (superstructure). In fact, there is other unit better describe the condition of vehicle loads on ro-ro vessels rarely used in Indonesia, namely, Lane Meter. Lane Meter (LM) is a unit deck area for ro-ro ships in which one lane is represented by a width of 2 meters and a length of 1 meter (ibiblio, 2008). Moreover, lane meter describes the deck areas on a particular ship used for vehicle placement. Therefore, it is important to estimate the loading capacity of the ship, particularly in initial stage.

In ship design process, the initial stage is very critical because the design of a particular ship has to meet certain requirements. Ordinarily, the ship design process is carried out to follow in a spiral design process consisting of several stages, namely, Concept Design, Preliminary Design, Contract Design, and Detail Design (Watson, 1998). At Concept Design stage, the main ship size components like length between two perpendiculars (LPP), breadth (B), draught (T), and height (H) are determined. In the process of determining the ship particular, ship owner requirements are used to identify load specifications. Besides GT, a measurement in LM can be used to start the design process. In this study, Lane Meter measurements will be based on ships operating in Indonesian waters and will be correlated with the particular of the ship. This will shorten the spiral design process.

2 RESEARCH DESCRIPTION

This study aims to determine the correlation between the value of GT and LM on ro-ro ships to ship main dimensions in order to obtain mathematical models that correlates with the value of LM. The theoretical benefit of this research is to give an alternative mathematical model for determining the size of ro-ro ships under 2000 GT and 90 m. The practical benefit of this research for naval architects is to shorten the design process in determining the main size the ships under study.

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This research was carried out under the following procedures:

2.1 Literature Review

2.1.1 Cargo Mass Unit

At the beginning of the design process, a ship is always delivered about the original purpose of shipbuilding. As a means of transportation, ships are intended to transport several goods frequently referred to as cargo. In most cases, cargo can be defined as goods transported by a means of transportation for commercial purposes. There are many forms of cargo, ranging from bulk, dry bulk, containers, or even something in units. In addition, the cargo itself is divided into several units that have been agreed globally. The cargo mass units commonly used on ships can be stated as follows (Marine Environment Protection Committee, 2009):

- For dry cargo carriers, liquid tankers, gas tankers, ro-ro cargo ships and general cargo ships, the units of cargo transported are using metric tons (t);
- For container ships that only handle containers, they must use the number of containers (TEU) or metric tons (t) of the combined mass of the cargo and containers;
- For ships carrying a combination of containers and other loads, a 10 t TEU mass can be used to load TEUs with payloads and 2 t for TEUs with empty loads; and
- For passenger ships, including ro-ro passenger ships, must employ the number of passengers or gross tonnage of the ship (GT);

In some cases, the mass unit of cargo used can be stated as follows:

- For car ferries and car carriers, must employ the number of car units or lane meters occupied;
- For containers, total TEU (empty or full.); and
- For railroad carriers and ro-ro vessels, the number of carriages and vehicles carried, or lane meters occupied.

2.1.2 Gross Tonnage

Gross tonnage is the calculation of the volume of all space located below the deck of the ship plus the volume of the enclosed space located above the deck with the contents of the room along with all the enclosed spaces located above the top deck (superstructure). Gross tonnage is expressed in tons, which represent a unit volume of 100 cubic feet, which is equivalent to 2.83 cubic meters (IMO, 1969).

In its application to the Ro-Ro Ferry, the GT is used to express the unit size of the Ro-Ro ship. Following KM 53 of 2002 (Menteri Perhubungan R.I., 2002), the Ferry port classification is divided into 3 (three) classes based on the vessel GT capacity. At Class-I Ferry Port, the dock used to accommodate ships with a size above 1000 GT. Class-II Ferry Port, the pier used to accommodate ships with capacities ranging from 500 GT to 1000 GT. Whereas at Class-III Ferry Port, the dock used to accommodate ships with a capacity of under 500 GT.

As part of the size of the Ro-Ro ferry, the value of the gross tonnage of the ship does not represent the exact dimensions of the ship. Based on data obtained in 2012 in previous studies (Asri, 2016), several ships with larger main sizes have smaller gross tonnage than other smaller vessels. And also explained that there are some ships with the same main dimensions but have different tonnage. It is because the value of gross tonnage itself is a function of closed space. Whereas every ship with the same main dimensions could have various enclosed spaces so that might produce different gross tonnage calculations. On the other hand, gross tonnage more represents the capacity of the loaded passenger space.

2.1.3 Lane Meter

In addition to using the gross tonnage units (GT) the vehicle carrier equally has other capacity units. Ro-Ro cargo ships are usually measured using lane meters (Wathne, 2012). Lane meter represents a method of measuring Ro-Ro ship space capacity where each unit of space (linear meter) represented by a deck area with a length of 1.0-meter and width of 2.0 meters (IFA, 2006).

Typically, ro-ro ships occupied a loading space to transport vehicle which typically arranged lengthwise on the deck. The placement of vehicles on this ship was divided into several loading lanes. As explained before, the Lane Meter (LM) unit is described as a deck area of one lane with a width of two meters and one meter long, or the equivalent of 2 square meters (21,528 square feet). Practically, the LM unit represents the combined length of the entire lane in meters that can use to load vehicles on ro-ro ships. In its application, the size of a conventional car in Europe will require an area of six LM, and for European semi-trailer trucks require an area of 18 LM.

The strength of the lane meter is it typically reflects the number of vehicles that can be properly loaded on the car deck. By using a lane meter, whatever the length of the vehicle can be equalized by managing this unit. Which represents the overall length of the lane on the ship that can accommodate vehicles on the deck. When synchronized, it can properly explains that by using functional capacity of

100 LM, the ship can transport a possible total of 20 operational units of Gol IV vehicles with a length of 5 meters . It can transport 10 Gol V Trucks with a length of 7 meters and 6 privates Gol IV vehicles. Compared to the Gross Tonnage unit with a value of 300 GT, the number of vehicles that can be loaded by the ship could not be precisely ascertained. So far, the practitioners only have predicted based on their intuition by comparing with the size of the ship they knew.

Disadvantages of lane meter unit is that the remaining unit of weight is unable to represent the payload directly. The definition of this unit, nevertheless, followed by some debates in practice. Although by definition it is known that the width of the lane referred to in the lane meter is two meters, but in practice, some vehicle types occupy a width of more than two meters.

In terms of loading on ships in Indonesia, the loading of vehicles on ships has been regulated in the Technical Guidelines for Minimum Service Requirements for River, Lake, and Crossing Vessels (Direktorat Jenderal Perhubungan Darat, 1994). The regulation stipulates that the distance between vehicles when loading on board is 0.6 m (600 mm). While the distance of the vehicle to the ship's wall is 0.6 m (600 mm). Concerning the description of the LM unit, which occupies a width of two meters and the ministerial regulation. It can be equalized that one lane of vehicles on a ship provides a width of 2.6 m with an additional 0.3 m per side. So that the arrangement of vehicle lanes by implementing these requirements represents the preparation of LM values on the deck of the vehicle and accommodate variations in the width of the vehicle that is on the ship.

2.1.4 Present Ship Sizing by Lane Meter

Determination of the main dimensions of a ro-ro ferry boat using input lane meter values has been done before (Kristensen, 2006). This study utilized data from ro-ro vessels of 500 to 3500 LM. Using statistical analysis, a mathematical model was obtained. It shows the correlation between LPP and LM that is defined by the equation:

$$Lpp = 110 + (LM - 1000) / 25 \qquad (1)$$

Where:

Lpp : *Length between perpendicular*

LM : *Lane meter*

The subsequent research was conducted again (Kristensen, Analysis of technical data of Ro-Ro ships, 2016), with discussions focused on Ro-Ro ships. The data in the study were widely analysed based on various parameters that have been collected and examined to develop a formula for the systematic calculation of technical data on Ro-Ro cargo ships. So we obtain 2 (two) conditions stated in the following equation:

$$Lpp = 20.4LM^{0.259} \text{for } LM < 1.402 \qquad (2)$$

and

$$Lpp = 11.18LM^{0.342},\ LM \geq 1.402 \qquad (3)$$

The other variables can be obtained using the followings:

$$B = 5.49LM^{0.192} \qquad (4)$$

$$T = 1.9LM^{0.16},\ LM < 2.000 \qquad (5)$$

$$T = 5.81 + 0.0003LM,\ LM \geq 2.000 \qquad (6)$$

$$D = 0.00172LM + 11.42 \qquad (7)$$

Based on data displayed by (Kristensen, 2016), the length of the ship shown has an average LPP size above 100 m. The determination of the equation for ships with LPP size below 100 m needs to be reviewed mathematically.

Based on data showed in Table 1, the mathematical model presented, has a relatively significant deviation compared to the initial value. With an average difference of 97% and 68% of the genuine value. Typically, there is an improvement that occurs between the equations defined by Kristensen from equation (1) to equation (2), where the difference gets closer. For this reason, it is necessary to make adjustments to ships in Indonesian waters.

Table 1: Comparison of Krinstensen's LPP calculations with the reality.

Ro-Ro	GT	LM	LPP (Real)	LPP (2-1)	Dev (2-1)	LPP (2-2)	Dev (2-2)
A	288	50	33,50	72,00	215%	56,19	168%
B	560	90	40,15	73,60	183%	65,43	163%
C	634	126	41,35	75,04	181%	71,39	173%
D	1120	137	50,50	75,48	149%	72,95	144%
E	284	44	28,32	71,76	253%	54,36	192%
					197%		168%

2.2 Lane Meter Variable Measurement

At the beginning of this study, the value of LM was unknown. Therefore, it is necessary to measure it first. To measure the value of LM, this study used 94 ro- ro ships with sizes below 2000 GT and 90 m length. Lane Meter (LM) measurements are obtained by re- sketching the car deck arrangement based on the general arrangement drawings or similar that have been collected previously. LM measurements are adjusted according to the description in 2.1.3. In the shown one of the LM measurement values that will be used as variables in this study.

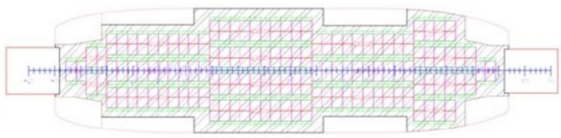

Figure 1: KMP Kormomolin 884 GT 77 LM.

2.3 Correlation Test

Correlation coefficient is a statistical measurement of covariance or association between two variables. The value of the correlation coefficient has a range between +1 and -1. The correlation coefficient shows the strength of the linear relationship and the direction of the relationship of two random variables. If the correlation coefficient is positive, then the two variables has a direct relationship.

2.4 Linear Regression Analysis

Regression analysis explores the relationship between one or more variables/independent variables (X) with one dependent variable (Y). A form of relationship related to response (Y) and regressor (X) represents a linear relationship, which can be written as follows (Walpole, 2012):

$$Y = \mathrm{a} + \mathrm{b}x \tag{8}$$

Here, (a) is called intercept and (b) is the direction coefficient or beta coefficient.

3 DATA ANALYSIS

3.1 LM and GT Correlation Test

In this study, the correlation value (r) was obtained using Pearson's Correlation theory. Correlation calculations performed on LM as an independent variable on many dependent variables included in the main dimensions of the ship. The dependent variable considered to be determined in this study. The value is GT, LOA, LPP, B, T, H, L/B, L/T, B/T, and Payload. Several correlation tests were also carried out on the dependent variables. There are LM, LOA, LPP, B, T, H, L/B, L/T, B/T, and Payload, using GT as an independent variable. From this process, we will determine which variables are correlated with LM values. Correlation value has a range starting from the value of "zero" which means there is no correlation at all. The correlation value of "one" means it has a perfect correlation value. Performed by statistical correlation calculations, the correlation results obtained were shown in Table 2.

Table 2: Correlation Test Results.

Correlation	LM	GT
LM	-	0,884
GT	0,884	-
LOA	0,912	0,845
LPP	0,914	0,847
B	0,874	0,817
T	0,726	0,737
H	0,713	0,723
L/B	0,525	0,487
L/T	0,416	0,297
T/H	0,392	0,393
B/T	-0,051	-0,139
Payload (ton)	0,651	0,624

Table 2 explains that the Lane Meter variable provides a direct correlation to the variables GT, LOA, LPP and B on ro-ro ships, compared between the dependent variables between LM and GT. It could be concluded that LM provides a more exact correlation than GT on LOA, LPP, B, L/B and Payload values. The T and H values better correlated to the GT variable than LM.

3.3 Regression Modeling

3.3.1 Regression Model of GT

Linear regression analysis is used to find out how much effect the gross tonnage value (GT) has on Lane Mater (LM) and obtain its mathematical model. Based on the model, it is recognized that the value of the coefficient of determination R square = 0.825. It shows that the effect of the Lane Meter (LM) on gross tonnage (GT) is 82.5%. Based on the ANOVA test, results obtained showed significance value of 0.000 (< 0.05), thus resulting regression model can be used to predict the variable GT. The coefficient calculation results explained a constant value of -31,382 while the Lane Meter value (regression coefficient) of 6,034 so that the regression equation can be written with:

$$GT = -31{,}382 + 6{,}034\, LM \qquad (9)$$

Based on the results of tests conducted, it can be concluded that Lane Mater (LM) affects GT value. The resulting regression equation can described by following Figure 2.

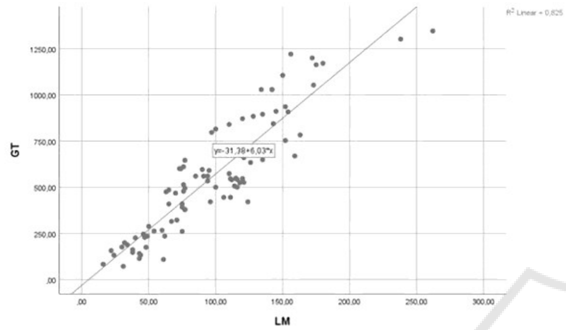

Figure 2: Regression of LM – GT.

3.3.2 Regression Model of LOA

Linear regression analysis is used to find out how the value of the overall length of the ship (LOA) has a significance effect towards the lane meter (LM) in order to obtain the mathematical model. Based on the model performed, it was recognized that the value of the coefficient of determination R square = 0.832, which shows that the effect of the Lane Meter (LM) on the overall length of the ship (LOA) of 83.2%. Based on the ANOVA test, results obtained a significance value of 0,000 (< 0.05), then the resulting regression model can be used to predict LOA variables. The coefficient calculation results indicated a constant value of 22,632 while the lane meter value (regression coefficient) of 0.223 so that the regression equation can written by:

$$LOA = 22{,}632 + 0.223\, LM \qquad (10)$$

Based on the results of tests conducted, it can be concluded that Lane Meter (LM) affects the LOA. The following regression equation can be described by Figure 3.

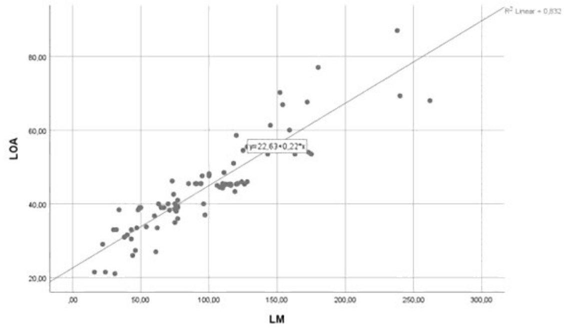

Figure 3: Regression of LM – LOA.

3.3.3 Regression Model of LPP

Linear regression analysis was used to find out how much effect the length of the ship's vertical line (LPP) on the lane meter (LM) and obtain the mathematical model. Based on the model performed, it could be recognized that the value of the coefficient of determination R Square = 0.835. It shows the effect of LM on LPP is 83.5%. Based on the ANOVA test, results obtained a significance value of 0.000 (< 0.05), therefore the resulting regression model can be used to predict LPP variables. The result of the coefficient calculation shows the constant value is at 20,039 while the Lane Meter value (regression coefficient) is at 0.197 so that the regression equation can be written with:

$$LPP = 20{,}039 + 0.197\, LM \qquad (11)$$

Based on the results of tests conducted, it concluded that Lane Mater (LM) affects LPP. The resulting regression equation can be described with the following by Figure 4.

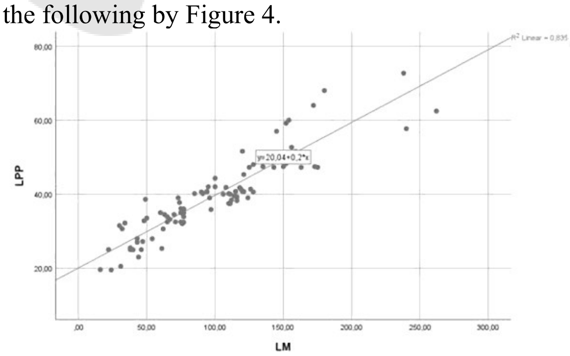

Figure 4: Regression of LM – LPP.

3.3.4 Regression Model of B

Linear regression analysis was also used to find out how much effect the value of the width of the ship (B) on the lane meter (LM) and obtain a mathematical model. Based on the model, it could be recognized that the value of the coefficient of determination R Square = 0.764. It shows that the effect of the independent variable in the form of lane meter (LM) to the dependent variable (B) attends 76.4%. Based on the ANOVA test results obtained a significance value of 0,000 (< 0.05), therefore resulting regression model can be used to predict B variables. The coefficient calculation result shows the constant's value of 7,698 while the lane meter value (regression coefficient) of 0.038 so that the regression equation can written by:

$$B = 7{,}698 + 0.038\,LM \qquad (12)$$

Based on the results of the tests conducted, it can be inferred that Lane Mater (LM) affects B. The resulting regression equation can be described by the following Figure 5.

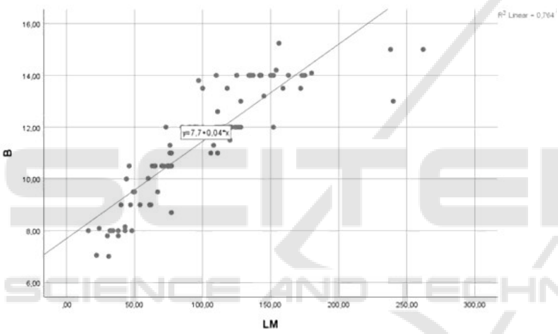

Figure 5: Regression of LM-B.

3.4 Model Comparison

In order to find out the accuracy of mathematical models, a comparison must be performed between the real LPP variable values and the LPP calculations. LPP calculations was obtained by using the equation (11). Using the compared result in Table 2, it was inferred that the LPP value produced provided quite a considerable accuracy with a difference of 3% for the sample ship. When compared with the equations (1) and (2) in Table 1 the value is already more representative of the initial value.

Table 2: Comparison model (11) to real LPP.

Ro-Ro	GT	LM	LPP (Real)	LPP (11)	Dev (11)
A	288	50	33,50	29,89	89%
B	560	91	40,15	37,97	95%
C	634	126	41,35	44,86	108%
D	1.120	137	50,50	47,03	93%
E	284	44	28,32	28,71	101%
					97%

The variable B was also compared between the value of the real variable B and the B calculation. The B calculations are obtained by using the equation (4) and the equation (12). From the results in Table 3. It could be seen that the value of B produced provided quite a precise accuracy with a difference of 1% for the sample ship. When compared to the equation (4) with a difference of 15%, the value produced by (12) is much closer to the initial value.

4 CONCLUSION

1. Based on the results of the correlation test, Lane Meter provides a very strong correlation to the variables GT, LOA, LPP and B on ro-ro ships. Where the value of each of these variables is GT: 0.884, LOA: 0.912, LPP: 0.914, B: 0.874.
2. Based on the results of the correlation test, LM values provide a more exact correlation than GT on LOA, LPP, B, L/B and Payload variables on the main size of ro-ro vessels.
3. For a very strong correlation, a mathematical model is adopted to estimate the ferry ro-ro with a size below 2000 GT and a length below 90 m:
   - LM against GT
     $GT = -31{,}382 + 6{,}034\,LM$, R^2 0.825
   - LM against LOA
     $LOA = 22{,}632 + 0.223\,LM$, R^2 0.832
   - LM to LPP
     $LPP = 20{,}039 + 0.197\,LM$, R^2 0.835
   - LM against LPP
     $B = 7{,}698 + 0.038\,LM$, R^2 0.764

Table 3: Comparison model (4) and (12) to real B.

Ro-ro	GT	LM	B (Real)	B (4)	Dev(4)	B (12)	Dev (12)
A	288	50	9,50	11,64	122%	9,60	101%
B	560	91	12,00	13,05	109%	11,16	93%
C	634	126	12,00	13,89	116%	12,49	104%
D	1120	137	14,00	14,12	101%	12,90	92%
E	284	44	9,00	11,35	126%	9,37	104%
					115%		99%

4. Based on model comparison, this model representation was closer to the initial value of ro-ro ships than the present model.
5. In determining T and H values, another approach which is more correlated than the Lane Meter was needed.

As stated above, this research is in accordance with the results of this study. The result equations in this study represents more about the size of ro-ro ships in Indonesia compared to previous studies.

For upcoming studies, the correlation between the LM and the main dimensions of the ro-ro ship above 2000 GT could be more analysed. After obtaining the main dimensions of the ro-ro ship, further analysis on the relationship between the LM and the weight of the ship can be carried out. This is considered very helpful for the ship design process. After obtaining the main size and the weight of the ro-ro ship, the construction costs can be estimated.

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