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To cite this article: A Azhar and T A Kristiyono 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **972** 012014

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Method for Estimating Cost of New Ship Building with Linear Regression

A Azhar¹, T A Kristiyono²

^{1,2}Naval Architecture and Ship Building Engineering, Hang Tuah University of Surabaya, Jl Arif Rahman Hakim 150, Surabaya, Indonesia.

E-mail: ali.azhar@hangtuah.ac.id

Abstract. The request of a fleet of marine transportation can be fulfilled by constructing new vessels and purchasing secondhand vessels. The current constraints in building new vessels are cost relatively expensive and take a long time, while the advantages for the procurement of vessels of secondhand time relatif faster and the price is cheaper. New shipbuilding includes complex work with the multy year's payment system, so it is important to develop the cost budget needed to build a new ship. The price should be adjusted concerning material needs and services with the standard market price during the completion time of the work and expected the calculation of the construction of a ship can be updated periodically. The research aims to identify, analyse and construct the cost estimation of the construction of the ferry types: 300 GT, 500 GT, 600 GT, 750 GT and its components. The stages that will be carried out in this study are to identify primary and secondary data relating to the construction costs of ferries and their components with field surveys, market surveys, and relevant library studies. Data is processed by linear regression methods to construct an estimate of the cost of building ferries and their components. Results obtained in the form of graphs and equivalencies of the cost of building ferries and material cost components, labour costs, and shipyard and third party costs.

Keywords: ferry, materials, labour, shipyards, third parties

1. Introduction

The Maritime vision and program "Sea toll " President of the year 2014-2019 is momentum and challenge for the development of the national ship industry in order to create independence and sovereignty of the Indonesian maritime continent. The sea toll is effective marine connectivity in the form of vessels that surf regularly and scheduled from the west to the east of Indonesia. Fleet support in order to implement the sea toll Program consists of 3,000 PELRA ships, 250 ASDP ships, 260 pioneer ships, 14,300 commercial ships [1]; (figure 1). The vessel serves to support the acceleration of national economic growth and increase inter-island connectivity in remote areas as well as to ensure the availability of basic materials and growth of trade centres and industries.

The request of a fleet of marine transportation can be fulfilled by constructing new vessels and purchasing secondhand vessels. The current constraints in building new vessels are cost relatively expensive and take a long time, while the advantages for the procurement of vessels of secondhand time relatif faster and the price is cheaper.

Ship building that includes ship design and ship building is a very competitive business. When a shipyard company has won tender construction of the ship, one that must be considered is a limited time given by the ship owner in completing the construction of the ship. The bidding process starts with a not binding first based on a short specification and ends up to a binding offer based on a more detailed



specification. If assumed two different shipyard that has the same technology quality, then the final price will be the deciding factor.

The cost structure of building new and secondhand ships is very different. The cost structure of the construction of the new ship consists of five basic parts that are considered for assessment, namely: hull construction; deck machinery; ship propulsion system; auxiliary machinery systems, so that the financing structure refers based on these five elements and the method of approaching the cost with gross tonnage per USD [2].

Studies related to the determination of the price of secondhand vessels can be done by using a static method to calculate the price of secondhand tankers [3]. The estimated price of secondhand vessels can also be determined in the form of percentage reductions based on the life of the vessel [2] (table 1). Other more comprehensive methods are market price, comparative vessel and physical ship price, and the estimated ship price is obtained from the average value of the three methods [4].

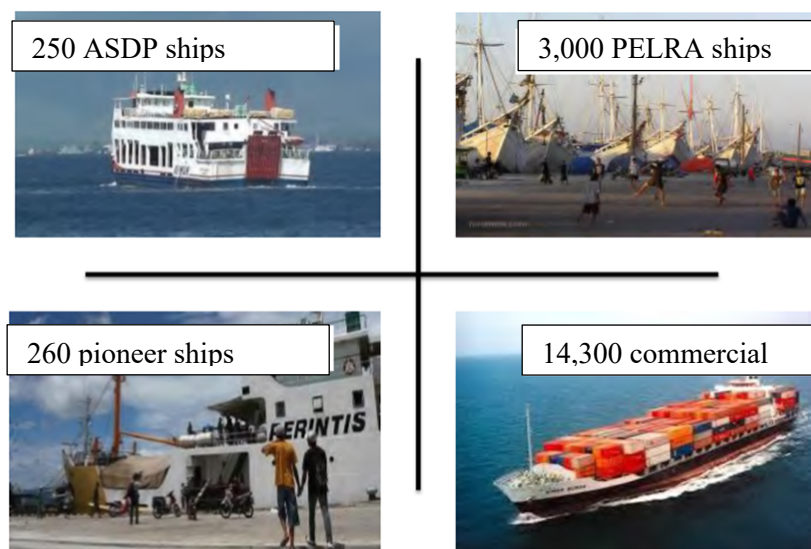


Figure 1. Fleet support in order to implement the sea toll program [1]

The cost component of building a new ship from the results of another study consists of tangible and non-tangible factors [5]. Tangible factor consists of: hull, hull equipment, galley and mess room equipment, installation of machinery, motor aids & pumps - pumps, tanks - tanks outside the hull, equipment, moorings and flap, safety equipment, other equipment, machinery - deck machines, construction services & third party costs. While non-tangible factors consist of: port cost, classification cost, exchange rate, inflation, UMR (regional minimum wage), planning and development time, design drawing, design image authentication time, design image attestation time, design drawing by the third party, domestic component level (TKDN), and others. Some very important points that are related and can be referenced are exchange rate, inflation, UMR (regional minimum wage),

The estimated price of new ship construction is based on the experience of several shipyards over the decades and the unit size of gross tonnage (GT) per USD [2] (table 1), the mathematical approach formula can be used to estimate the cost of building dry bulk vessels, containers and tankers based on the main size of the ship [6]. Pioneer shipbuilding price standards are obtained by regression equations for material costs, construction service costs and third party costs that can be updated every year and ship-based development in 2015 [5].

Table 1. Cost of building new ships [2]

No	Ship type	Unit	Magnitudes (US \$)	Foreign shipyard
1	Passenger ferry-vehicle	GT	2000-3500/GT	500-1500/GT
2	Barges	Feet	2000-2500/GT	700-1000/GT
3	Oil tanker	LT DWT	650-800/LTDWT	450-600/LTDWT
4	Container	TEUS	6500-7500/TEUS	4000-5500/TEUS
5	Fishing vessels	GT (wood)	4500-6000/GT	4000-5000/GT

A more comprehensive and sustainable concept relating to the identification of factors affecting the construction price of new ships based on the Pentaple Bottom Line plus R will be simulated and classified that adopt and accommodate influential factors [7]. Factor 3P is: (1) People related to the level of education of the workforce, number of labour, ability and expertise; (2) Planets related to climatology, shipyard facilities and infrastructure; (3) Profit related to investment and operational costs, profitability, market share, lending rate, inflation, UMR (regional minimum wage), dollar exchange rate. The addition of the next 2 factors is (4) PhenoTechnology related to production technology, production quality, productivity, ship size, raw materials, design, waste material (5) Prophet/prophet can be associated with the spiritual and mental balance to behave taqwa, honesty, trust and love for work and the natural environment. To accommodate a fairly important factor in the price of new ship construction needs to be added factors related to regulation, so that the approach is based pentaple bottom line plus R. R (Regulation) related to technical regulations, government and stakeholder support, Domestic Component Level. The number of variables that affect ship prices results in more detailed price estimates, but the supporting data required is very large and complex, both quantitative and qualitative.

During this estimate, the cost of building a ferry each type refers to the funds set by the owner, so that the technical specifications adjust. The work of shipbuilding includes complex work with the payment system multy years, so it becomes very important to compose the cost budget or price needed to build a new ship. The variables in this study are the price of the ship and the ship's GT, with the consideration that the ship's GT includes the volume of the ship's enclosed space and is used as a reference for various statutory regulations. Sub-variables of ship price components are based on experience from national shipyards consisting of labor, materials and shipyard costs and third parties. Other sub-variables considered are the dollar exchange rate, inflation and the increase in regional minimum wages. Estimated price of new shipbuilding, especially ferry ships that have been built by the national shipyard industry consists of 300 GT, 500 GT, 600 GT and 750 GT. (Figures 2, 3, 4, and 5); [8]. The purpose of the research is to identify, analyze and arrange the cost of construction of the price of ferry type: 300 GT, 500 GT, 600 GT, 750 GT and its components The price must be adapted to the needs of materials and services with standard market price During the completion of the work and expected the calculation of the cost of construction of ferries can be updated periodically.

**Figure 2.** KMP Bambit 300 GT



Figure 3. KMP Trisila Bhakti II. 500 GT



Figure 4. KMP Tuna 600 GT



Figure 5. KMP Wayangan 750 GT

2. Method

The estimation of the cost of constructing the ferry and its components can be seen in Figure 6, starting with identifying problems and collecting primary and secondary data through literature review, field surveys and market surveys. Literature review is related to price theories and components, and previous research that discusses the price of new and used ships. Field surveys were carried out in several national shipyards that had built new ferry types and data obtained were the prices of ships and their components as well as technical specifications. Market surveys are also conducted on the internet site to add reference to ship prices, dollar exchange rates, inflation and increases in regional minimum wages. The data obtained in the form of primary and secondary data were processed and analyzed using the regression method in Microsoft Excel Worksheet software to estimate the estimated cost of building

a ship and its supporting components. The results obtained are in the form of a graph of the estimated cost of building a ferry and its components by considering the fluctuations in currency exchange rates, inflation and regional minimum wages during the construction process as well as other relevant factors. The discussion was conducted to discuss the results of the estimation method that has been compiled compared with other relevant methods, so that a suitable method is obtained to be implemented.

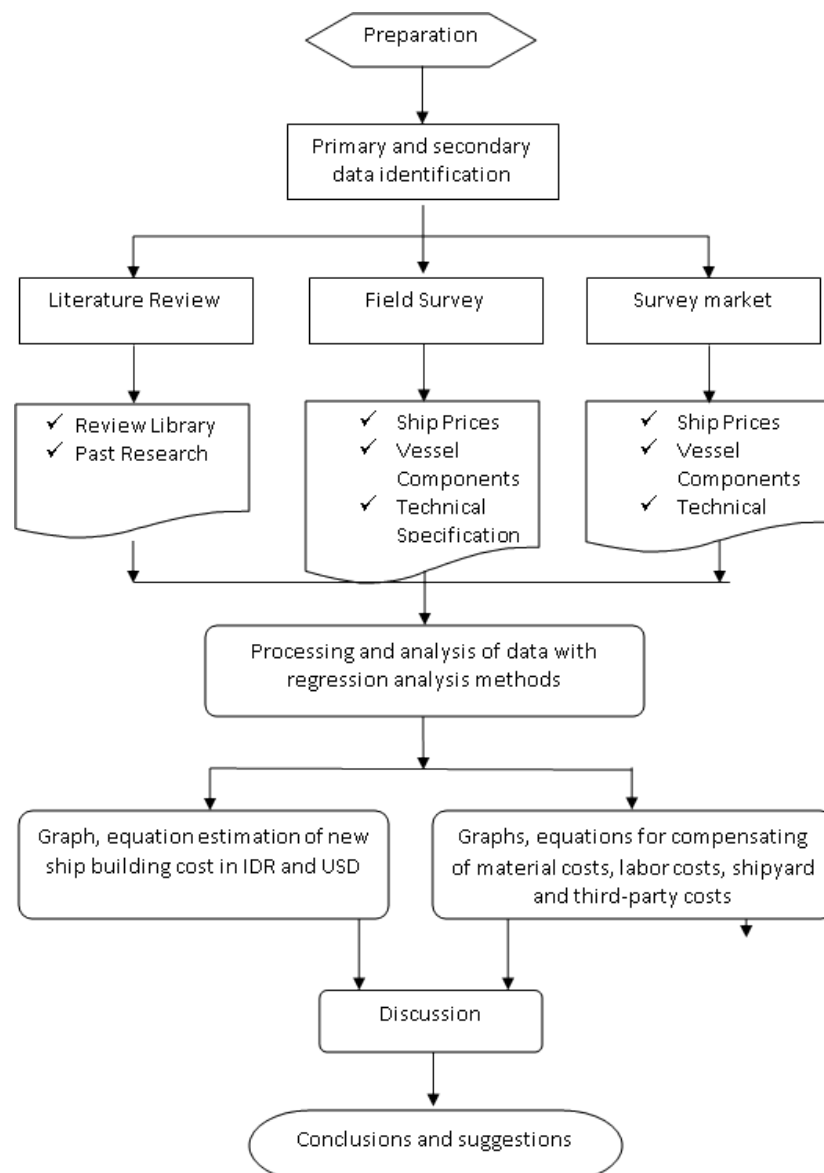


Figure 6. Research methods.

3. Results and Discussion

3.1. Ferry Construction Cost estimation

The arrangement of the Ferry construction costs and their components using primary and secondary data will be processed by a linear regression method to estimate or estimate the cost of the vessel and its supporting components. The result obtained is a linear graph in the form of an equation of the cost of building a ferry in IDR and USD (figure 7). The cost of ship building is based on some data on ferry ship construction in Indonesia that has been contracted in 2015. Based on some data obtained from the

shipyard can be known the construction cost of Ferry 300 GT, 500 GT, 600 GT and 750 GT, and equality of construction cost of Ferry based on GT (IDR x 1000) are:

$$Y_{KIDR} = 18598X + 2E + 07 \text{ with } R^2 = 0.9414 \quad (1)$$

where Y_{KIDR} = ship building costs in 2015 (IDR x 1000); X = GT

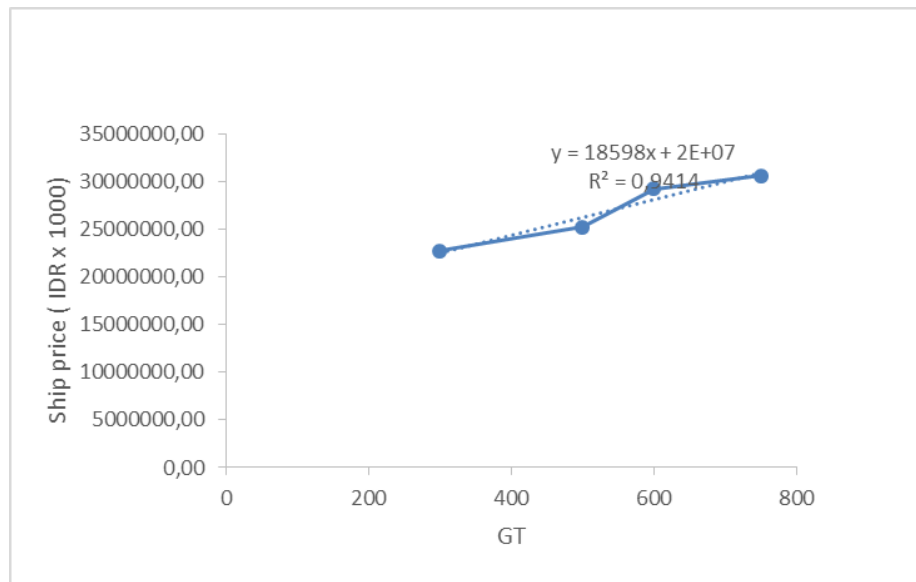


Figure 7. Equation of construction cost of Ferry (IDR x 1000)

The equation of the construction cost of ferries based on GT (USD) is:

$$Y_{KD} = 1359X + 1E + 06 \text{ with } R^2 = 0.9414 \quad (2)$$

Where Y_{KD} = ship building costs (USD); 1 USD = 13684.90 IDR (July 2015); X = GT

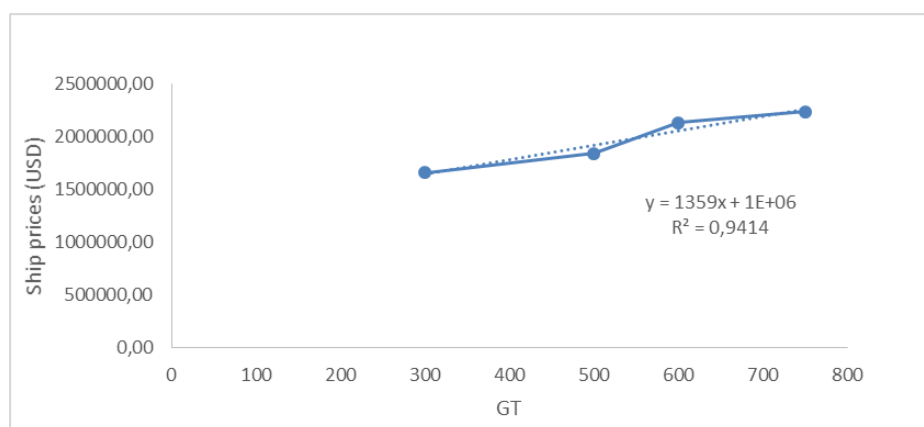


Figure 8. Equations of construction costs of Ferry (USD)

Figures 7 and 8 can be seen that the ferry construction cost equation in IDR and USD has different strands, but has the same coefficient of determination $R^2 = 0.9414$.

3.2. Cost estimation for Ferry construction component

Components of the cost of building ferries are essentially divided into three materials, labour, shipyard and third parties. Experience of several national shipyard industries in Indonesia, material costs amount

to 70% of the cost of hull and hull equipment work, machinery and deck fixtures, hotels and accommodation, machinery and propulsion systems, electrical equipment and lamps, additional equipment. The labour cost is 30% of the cost of gastric work and gastric equipment, machinery and equipment, hotels and accommodation, machining and propulsion systems, electrical equipment and lamps, additional equipment.

The maritime industry, especially shipbuilding, in building a vessel requires material, machinery and ship components where component components are still very dependent on foreign industrial products. More than 70% of ship components must be imported from other countries and greatly affect the price of the vessel, even if the shipyard is not careful in calculating the price of goods caused by inflation and dollar rate increase, then the shipyard will be Loss.

Table 2. Cost of material vessel based on ferry type (GT)

No	Ship type ferry (GT)	Material cost (IDR x1000)
1	300	13.043.165,240
2	500	14.535.479,000
3	600	17.439.360,904
4	750	18.101.345,150

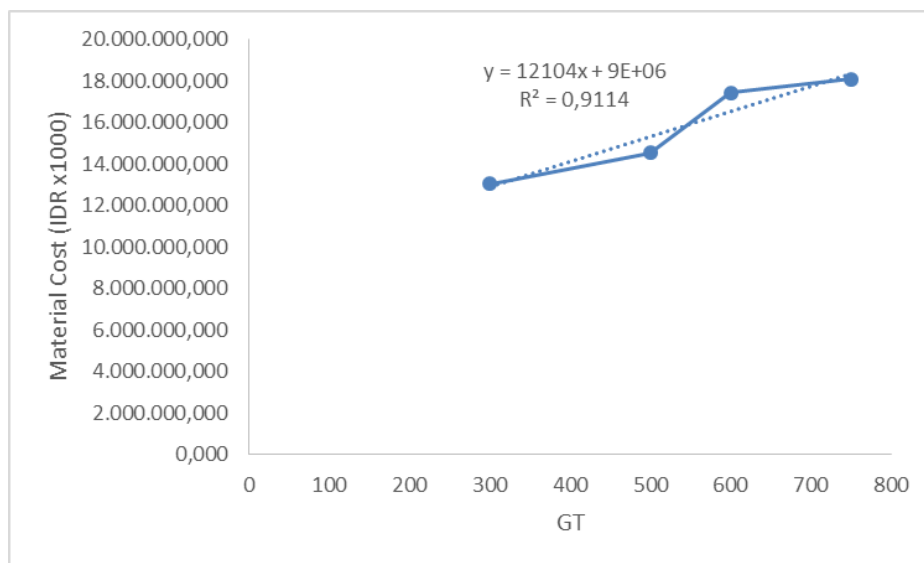


Figure 9. Material cost equation based on ship type Ferry (GT)

Based on data sourced from the Central Statistics agency [9] It can be seen that the average Indonesian inflation rate changes in the year 2015-2019 by 3.05%, and the dollar rate increase to the rupiah year 2014-2019 average of 4.65% [10]. Estimation of material component price should pay attention to inflation factor and dollar rate increase. So the equation of material cost estimation based on ferry type (GT) in figure 4 is:

$$Y_m = 12104X + 9E + 06 \text{ with } R^2 = 0.9114 \quad (3)$$

$$Y_{mn} = Y_m + Y_m (7, 7n/100) \quad (4)$$

Where Y_m = Material component Price (IDR x1000) year 2015; Y_{mn} = Material Component Price (IDR x1000) in year n; X = GT; n = year to – N (2015, $n = 0$)

The labor cost is 30% of the cost of gastric work and gastric equipment, machinery and equipment, hotels and accommodation, machining and propulsion systems, electrical equipment and lamps, additional equipment (table 3).

Table 3. Cost of labor based on ferry (GT)

No	Ship type ferry (GT)	Labor cost (IDR) x1000
1	300	5.589.927,960
2	500	6.229.491,000
3	600	7.474.011,816
4	750	7.757.719,350

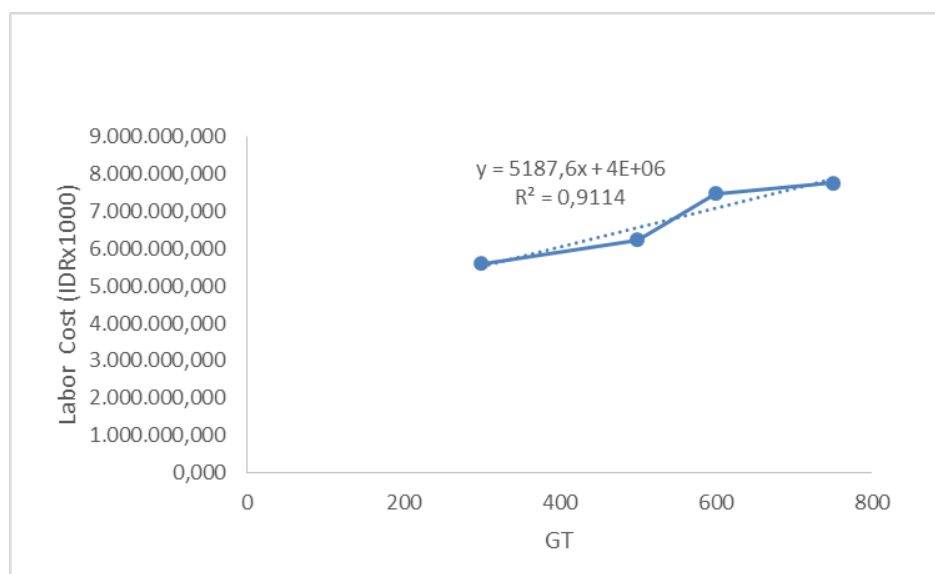


Figure. 10. Equation of labor cost based on ship type Ferry (GT)

A percentage of the regional minimum wage increase annually stipulated by the Ministry of Manpower has increased the increase in each year to experience a difficult change. This is because it is due to the provisions of the Ministry of Manpower based on Government Regulation (PP) Number 78 the year 2015 about the wage that uses the inflation rate and growth of the gross domestic product in establishing Increase in regional minimum wave [11].

Estimated labour component costs should pay attention to the increase in the regional minimum wave that considers the increase in inflation and gross domestic product growth. So the equation of estimated labour costs based on ferry type (GT) in figure 10 is:

$$Y_{TK} = 5187,6X + 4E + 06 \text{ with } R^2 = 0.9114 \quad (5)$$

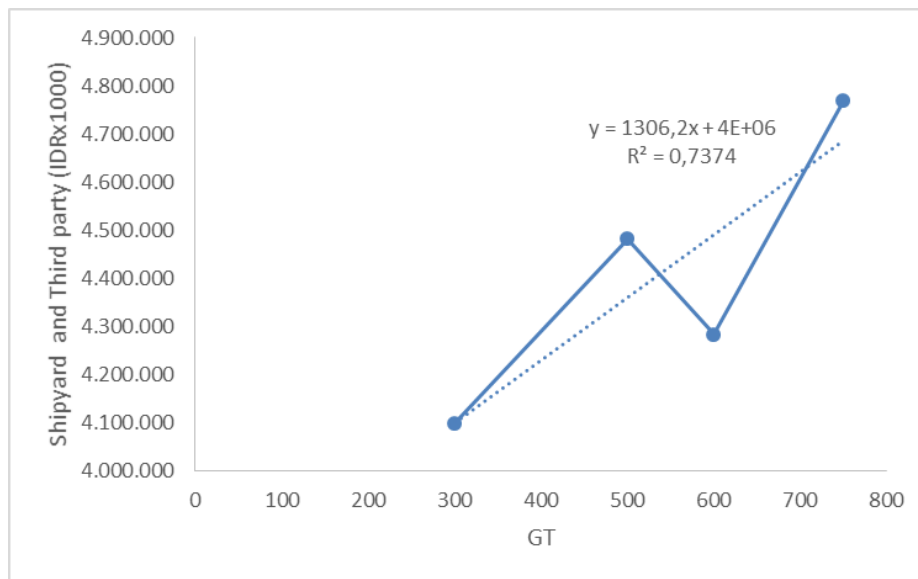
$$Y_{TKN} = Y_{TK} + Y_{TK} (8,05n/100) \quad (6)$$

Where is Y_{TK} = estimated labor cost (IDR x1000) in 2015; Y_{TKN} = Estimated labor cost (IDR x1000) n Year; X = GT ship; n = year to – N (2015, n = 0)

The cost component of the shipyard and third parties based on each ferry GT, the data obtained can be seen in table 4.

Table 4. Shipyard and third party fee based on Ferry (GT)

No	Ship type ferry (GT))	Shipyard and third party fee (IDR) x 1000
1	300	4.098.500
2	500	4.482.022
3	600	4.282.600
4	750	4.769.000

**Figure 11** The equation of shipyard and third party costs based on ship type Ferry (GT)

Estimation of components of the shipyard and third parties should pay attention to the inflation rate. Based on the data sourced from the Central Statistics agency [8] it can be seen that the average Indonesian inflation rate changes from 2015-2019 to 3.05%, so that the equivalent of the shipyard and third-party costs based on ship types are:

$$Y_{GK} = 1306,2X + 4E + 06 \text{ with } R^2 = 0.7374 \quad (7)$$

$$Y_{GKN} = Y_{gk} + Y_{gk} (3,05n/100) \quad (8)$$

Where Y_{GK} = Estimation of shipyard and third-party ship (IDR) for 2015; Y_{GKN} = component price of shipyard and third party ship (IDR) n Year; X = GT; n = year to – N (2015, $n = 0$)

3.3. Ferry Construction Price Estimation Comparison

The comparison of estimated prices of ferry construction aims to verify the regression equations that have resulted from the study. The comparison was done with gross tonnage cost per USD [2] approach method and contract data on the construction of several ferry ships from the national shipyard in July 2019. Based on table 5, the average price difference between the construction of 500 GT, 1100 GT and 1300 GT is 21.36%. A significant difference indicates that ship construction is an order product whose specifications and complexity depending on the demand of ship buyers. Another factor that is also influential is the uncertain condition of the world economy in recent years.

Table 5. Ferry construction price estimation comparison (IDRx1000)

No	Estimation method	GT		
		500	1100	1300
1	Adj [2]	24.806.200	54.573.750	64.496.250
2	Regresion	33.625.797	48.119.155	52.950.274
3	Price contract 2019	39.000.000	58.000.000	73.000.000
4	Price different 1-3 (%)	36,39	5,91	11,65
5	Price different 2-3 (%)	15,98	20,53	37,87
6	Average (%)		21,36	

3.4. Discussion

The determination of cost estimation of shipbuilding generally consists of the approach of comparative vessel approaches. This linear regression method also uses a comparison ship approach with various types. The comparison vessel selection factor is a very decisive level of accuracy of the approximate vessel price that will be constructed by this method. The benchmark ship specification should have similarities to the vessel that is predicted to cost in terms of ship type, main size, material, main machine and drive system. Estimated ship prices using the price of comparative vessels, first make the equation of ship price regression is a function of the GT of each comparative ship. Calculation corrected is done if the year of manufacture difference between the comparison vessel that has been grouped material costs, labor costs, shipyard costs and third parties with the vessel to be constructed taking into consideration the factors of inflation, Dollar and regional minimum wage. This approach is only specifically used to estimate the cost of building the ferry and in a certain period can be updated the variable is adjusted to the condition of the economy.

The linear regression equation for the estimated cost of building a Ferry in IDR and USD has different values, but has the same coefficient of determination $R^2 = 0.9414$. The equation for the cost estimation component for the construction of a ferry consists of: material and labor costs having the same coefficient of determination $R^2 = 0.9114$, construction service costs and third party costs have $R^2 = 0.7374$, meaning that the independent variable GT ship has a very significant influence on the dependent variable is the price of the ship, material costs and labor costs, construction service costs and third party costs. The difference in the estimated price of 21.36% (table 5) in the comparison of various price estimation methods with the real contract price for the construction of a ferry shows the complexity of the price of a ship, the need for more and more homogeneous comparison ship data.

Estimation of shipbuilding costs can also be done by the physical price approach of vessels, through the grouping of engineering work items. Each technique work item will be grouped the main and supporting material according to the needs of the number. The job of market surveys to various sources such as the Internet, logbook, manufacturers, suppliers, associations, supporting regulations are needed to know the prices and specifications. By the data that has been obtained, done the calculation of the whole work of engineering items and tax percentage according to provisions, to determine the cost estimation of ship development.

Both of these methods have advantages and disadvantages. Estimation of the cost of construction of the ferry using the built-in comparison vessel can be used to estimate the cost of building the ferry faster by inputting the size of a variable magnitude GT ship and years of ship development. Estimation of the cost of building ships with the physical price of vessels takes a relatively long time but more cost more real. So to get the ideal and complementary results, both methods can be used simultaneously.

4. Conclusion

The making of estimation of the construction cost of the ferry consists of: the equality of the cost of construction of the ferry based on GT (IDR x1000) is $Y_{KIDR} = 18598X + 2E + 07$ and the equivalent of the cost of building a ferry based on the GT (USD) is $Y_{KD} = 1359X + 1E + 06$. Component of the

equation of the cost of construction of the ferry consists of: (1) The equation of material cost estimation is: $Y_m = 12104X + 9E + 06$ and $Y_{mn} = Y_m + Y_m (7, 7n/100)$; (2) The equation of labor cost estimation is: $Y_{TK} = 5187, 6X + 4E + 06$ and $Y_{tkn} = Y_{tk} + Y_{TK} (8, 05n/100)$; (3) Equality of cost of development services and third party cost is $Y_{GK} = 1306, 2X + 4E + 06$ and $Y_{GKN} = Y_{GK} + Y_{GK} (3, 05n/100)$. Estimation of the cost of construction of the ferry using the built-in comparison vessel can be used to estimate the cost of building the ferry faster by inputting the size of a variable magnitude GT ship and years of ship development. Estimation of the cost of building ships with the physical price of vessels takes a relatively long time but more cost more real. So to get the ideal and complementary results, both methods can be used simultaneously.

Acknowledgments

Thank you to Hang Tuah University Surabaya and all parties who have helped with the publication activities in scientific forums.

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