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DESIGN AND CONSTRUCTION ANALYSIS OF A RIVER CRUISE BOAT USING AN ELECTRIC MOTOR DRIVE

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ABSTRACT

Surabaya has many large rivers, so it has tourism potential if the management can utilize the river. Surabaya needs a ship that can accommodate river cruising activities to maximize the river's potential. Fiber-based boats are suitable for these activities because fiber materials tend to be durable, lightweight, and easily made. Therefore the boat was designed using fiberglass, which had the primary size; 10 meters long, 2.3 meters wide, 1.2 meters high, and 0.5 meters draft. The primary size allowed the boat to carry 11 passengers, including one helmsman, in one trip. The boat used an electric outboard engine with four horsepower that could make the boat travel at a speed of 4 knots, so the ship required 20 minutes to make a trip. The overall cost to make the boat amounted to Rp.47.345.600

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INTRODUCTION

Indonesia has a lot of tourism potential, one of which is river cruising, this is because most cities in Indonesia must have at least one large river that can be used as a tourist attraction. River cruise tourism is an activity that invites tourists to travel along the river using small boats to enjoy the other side of the city's beauty through waterways.

River cruises generally use small boats made of fiber or wood with a capacity of 10 - 15 people. The design of the shape and size of the tour boat is strongly influenced by the environment in which the boat will operate. Tourist ships need a driving machine to be able to take tourists around the tourist area. In general, tourist boats use outboard engines as propulsion engines because of their small and compact shape. An outboard engine is a propulsion system for a boat or ship, consisting of a self-contained unit that includes an engine, gearbox, and propeller, which is designed to be installed outside the window above the door.(Sumardi et al., 2020)

Conventional outboard engines generally use engines with fossil fuels (petroleum). This certainly has a negative impact on the environment because the combustion process in the engine produces carbon substances which are one type of pollutant. Pollutants produced in fossil combustion are the biggest factor in air pollution(Made Astra, 2010). Air pollution is one of the causes of the greenhouse effect (GHG) warming which will then cause global warming (Ismiyati et al., 2014), besides the limited amount of fuel oil makes fuel prices increase so that the operational costs of tourist boats will also increase along with the increase in fuel oil prices.

Various renewable energies continue to emerge to replace the finite amount of energy. Renewable energy is a source of energy produced from energy resources that are sustainable if managed properly, including geothermal, wind, bioenergy, sunlight, water flow and fall, and the movement and temperature difference of the ocean layer.

Electricity is one of the renewable energies that can be generated continuously because electricity can be generated by utilizing geothermal energy, solar, water, sea/ocean, and bioenergy(Azhar & Adam Satriawan, 2018). Seeing this certainly encourages various parties to compete to utilize renewable energy to support environmentally friendly programs and reduce operational costs because the price of electrical energy tends to be cheaper than the price of fuel oil(Liun et al., 2014).

The Indonesian government is also aware of the importance of using renewable energy in community activities, this is evidenced by calling electric vehicles one of the solutions to reduce emissions in the transportation category. In order to realize the use of electric motorized vehicles the president has also issued an order to accelerate the development of battery-based electric vehicles.

In the world of shipping the use of electric motors as prime movers is not new, such as SMEs in NTB who have launched e-boats in collaboration with PLN(BIDANG IKP, 2021). The use of electric motors as the main drive of the ship is also one method to reduce vibration on the ship which is generally caused by the rotation of the engine in operation(Arisandhi et al., 2016).

METHODS

The initial stage of this research is to identify the problem. At this stage the identification and formulation of problems regarding the optimal shape and size of the ship in accordance with the environmental conditions where the ship will be used.

The literature study aims to get the appropriate theoretical basis so that the research results can answer all research objectives properly. The data obtained to support this research is obtained from published articles. The data needed in the process of working on this research include main size, line plan, general arrangement, ship construction, shipbuilding costs, and data that can be used to assist in the work of this research. Determination of the main size of this ship is obtained using the ship comparison method where data is collected on 5 similar ships that have been made which then use the number of passengers as a variable so that the main size of the ship will be obtained, if the main size is still not in accordance with the restrictions used, the main size of the ship is adjusted.

The process of drawing the line plan is carried out after the main size is obtained and then the general plan of the ship and the 3-dimensional model of the ship to be built are drawn. Cost calculations are carried out to estimate the total cost required to make one ship and to calculate when the BEP time is if the ship has operated in several conditions.

RESULTS AND DISCUSSION

The number of passengers will be the independent variable (X). Meanwhile, the Length of the Perpendicular (Lpp), overall ship width (B), ship height (H), and ship laden (T) will be the independent variables (Y). To determine the function of each pair of independent variables and independent variables using the help of a comparison tour boat. The number of comparison ships used is 5 units as in Table 1.

Table 1. Comparison Ship Data

No.	Ship Name	Capacity (Person)	L (m)	B (m)	H (m)	T (m)
1	Boat	10	8,2	4,6	1	0,4
2	Ellips 35 Glass Bottom	9	10,5	3,2	1,3	0,5
3	Cat Taxi	12	9,8	5,8	1	0,3
4	Ecocast	10	8	4,5	0,9	0,3
5	Greine	12	9,7	5	1,6	0,6

After obtaining the comparison ship data, the data is entered into the regression curve so that an equation or correlation value will be obtained to get the value (Y). The regression curve can be seen in Figures 1, 2, 3, 4.

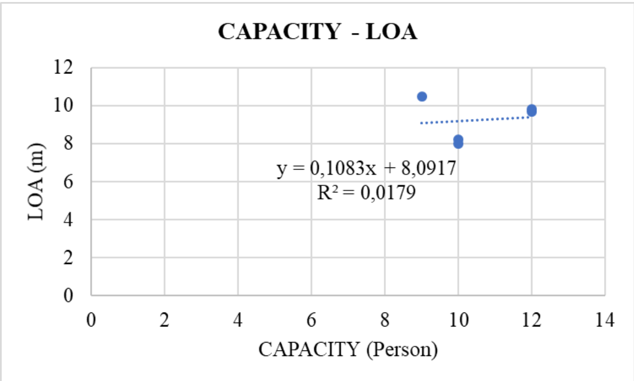

Figure 1. Capacity - LOA Correlation Regression Curve

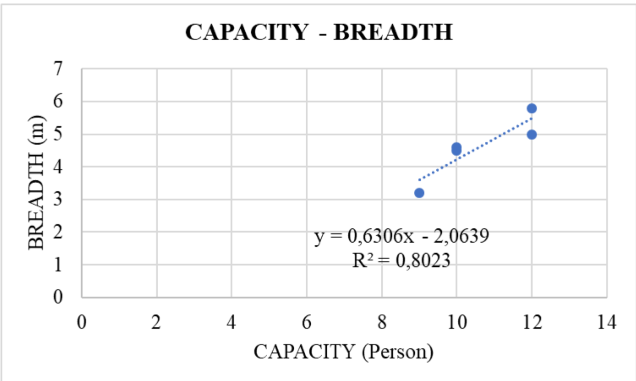

Figure 2. Capacity - Breadth Correlation Regression Curve

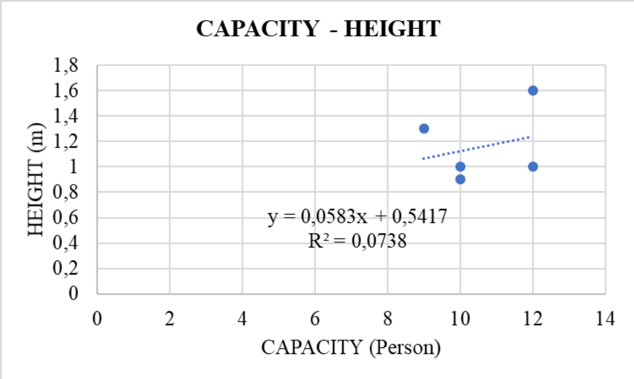

Figure 3. Capacity - Height Correlation Regression Curve

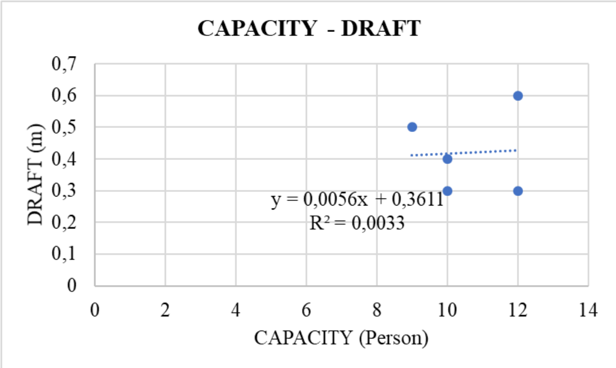

Figure 4. Capacity - Draft Correlation Regression Curve

After the correlation value is obtained, the value becomes the value (Y), and then the value (X) is entered, namely the passenger capacity of 11 people so that the main size value is obtained as in Table 2.

Table 2. Regression Results Table

No.	Parameters	Y	X	Result (m)
1	L (m)	8,0917 + 0,1083X	11	9,3
2	B (m)	-2,0639 + 0,6306X	11	4,9
3	H (m)	0,5417 + 0,0583X	11	1,2
4	T (m)	0,3611 + 0,0056X	11	0,4

The initial main size value is not the final size of the ship. If the regression results meet the constraints of the main size used, it can be directly used as the initial main size. However, if the regression results do not meet the constraints, then the initial main size can be increased or decreased until it is met. The initial main size and main size comparison constraints used in this thesis are:

L/B = 3.5 < x < 10 1.91
L/T = 10 < x < 30 21.99
B/T = 1.8 < x < 5 11.54
(Barrass, 2004)

Because the initial size does not meet the limitation requirements used, adjustments are made to the main size of the ship to :

L = 10 m
B = 2.3 m
H = 1.2 m
T = 0.5 m

So the ratio will change to :

L/B = 3.5 < x < 10 4.35
L/T = 10 < x < 30 20
B/T = 1.8 < x < 54.60

Line Plan Creation

The main size of the ship that has been obtained by the comparison ship method is then continued by making a line plan. Drawing lines plan using AutoCAD program. This is done to facilitate the calculation of the hull area and get a more precise ship size. Figure 5 is a line plan generated from the AutoCAD program:

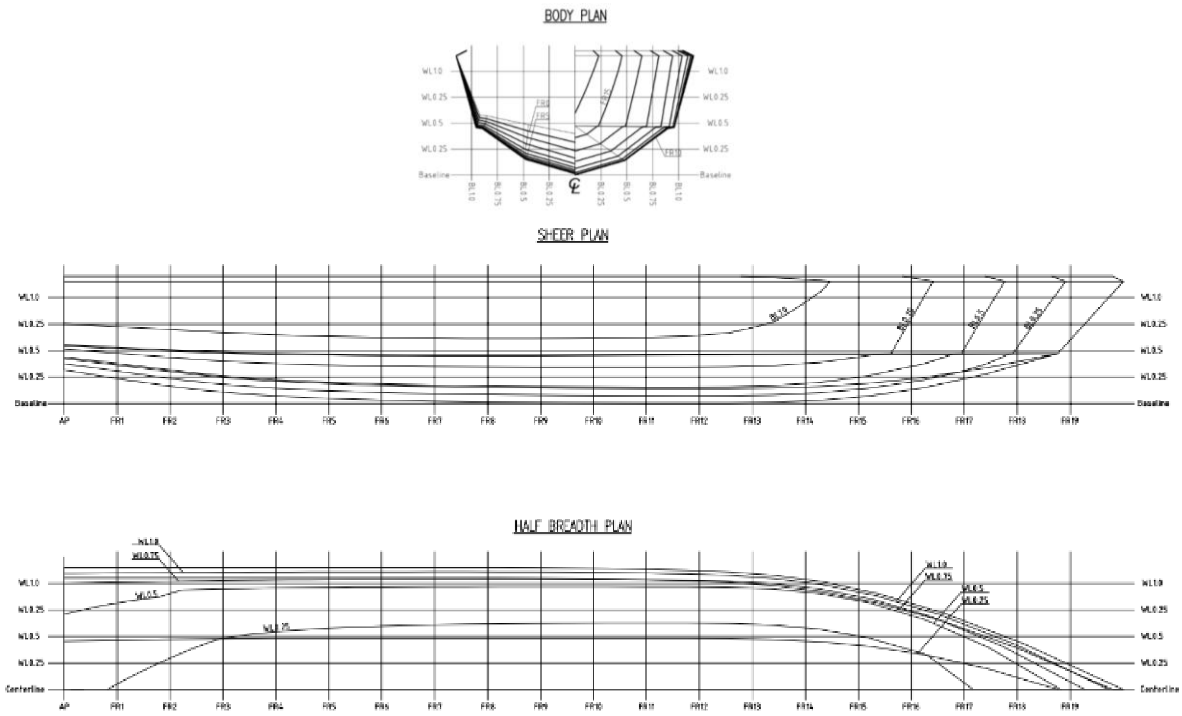

Figure 5. Results of Ship Lines Plan Drawing

General Plan Creation

In making a general design or general arrangement, an AutoCAD program is used, as well as making a line plan, the use of AutoCAD aims to get precise drawings so as to get an accurate picture of the ship's design. The thing that is taken into consideration in drawing the general plan is the layout of passenger seats because the ship is a type of tourist ship that must prioritize passenger comfort so that passengers can enjoy tours properly. Figure 6 is the result of a general plan drawing using the AutoCAD program:

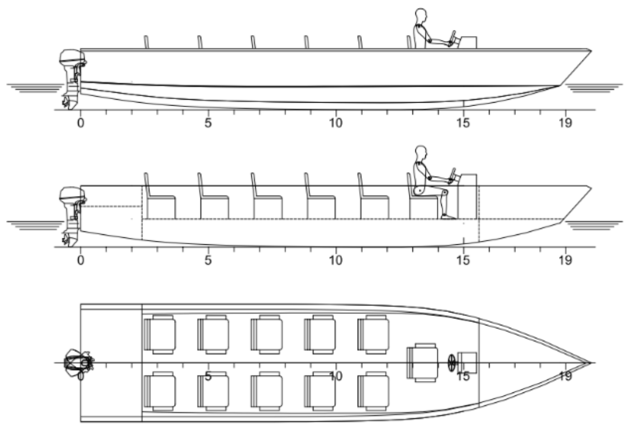

Figure 6. General Plan of the Ship

Power Calculation and Engine Selection

Power calculation is done to determine the engine that will be used so that the ship can work at its service speed. Engine power must be above the required power so that the engine does not work too hard which can shorten engine life or cause engine problems when the ship is sailing. Holtrop resistance (Rt) must be known before calculating power, therefore Maxsurf is used to know holtrop resistance when the boat runs 4 knots when service.

	Speed (kn)	Froude No. LWL	Froude No. Vol.	Savitsky Pre-planing Resist. (kN)	Savitsky Pre-planing Power (kW)	Holtrop Resist. (kN)	Holtrop Power (kW)
11	2,500	0,130	0,324	--	--	0,1	0,102
12	2,750	0,144	0,357	--	--	0,1	0,134
13	3,000	0,157	0,389	--	--	0,1	0,172
14	3,250	0,170	0,422	--	--	0,1	0,218
15	3,500	0,183	0,454	--	--	0,2	0,272
16	3,750	0,196	0,486	--	--	0,2	0,338
17	4,000	0,209	0,519	--	--	0,2	0,416
18	4,250	0,222	0,551	--	--	0,2	0,511
19	4,500	0,235	0,584	--	--	0,3	0,628
20	4,750	0,248	0,616	--	--	0,3	0,766
21	5,000	0,261	0,649	--	--	0,4	0,925
22	5,250	0,274	0,681	--	--	0,4	1,125
23	5,500	0,287	0,713	--	--	0,5	1,400
24	5,750	0,300	0,746	--	--	0,6	1,749
25	6,000	0,313	0,778	--	--	0,7	2,131

Figure 7. Result of Holtrop Resistance Using Maxsurf

Power calculation can be done using the formula below:

Effective Horse Power (EHP) Calculation

$$EHP = R_t \times v_s$$

$$EHP = 0{,}2 \times 4$$

$$EHP = 0{,}8 Kw$$

$$EHP = 1{,}07 HP$$

Since there is no electric outboard that has a power close to 1.07 HP, the author chose the Hangkai Electric Series 4.0 engine as shown in Figure 7. which has a power of 4 HP so that it meets the minimum power requirements for moving the ship.

Figure 8. Ship Engine Specifications

Material Requirement Calculation

In the process of building this tourist ship, the calculation uses the rule (BKI, 2021) as a reference for development calculations. Then the calculation of the thickness of the laminated glass fiber array is taken into account. The calculation is obtained from the equation (BKI, 2021)then the following results are obtained:

Mat thickness calculation (using mat= 300gr/m2)

$$t_M = \frac{W_g}{10 \times Y_R \times G} + \frac{W_g}{1000 \times Y_G} - \frac{W_g}{1000 \times Y_R}$$

$$t_M = \frac{300}{10 \times 1{,}2 \times 30} + \frac{300}{1000 \times 2{,}5} - \frac{300}{1000 \times 1{,}2}$$

$$t_M = 0{,}7 mm$$

WR thickness calculation (using WR = 600 gr/m2)

$$t_W = \frac{W_g}{10 \times Y_R \times G} + \frac{W_g}{1000 \times Y_G} - \frac{W_g}{1000 \times Y_R}$$

$$t_W = \frac{600}{10 \times 1{,}2 \times 50} + \frac{600}{1000 \times 2{,}5} - \frac{600}{1000 \times 1{,}2}$$

$$t_W = 0{,}74 mm$$

The size of each part is then calculated according to BKI rules in order to get the appropriate size. The results of these calculations are shown in Table 3.

Table 3. Section size calculation

Section	Width (mm)	Thickness (mm)	Area (m)^2
Keel	676	13	6,76
Bottom	-	6,88	27,06
Side shell	-	6,53	53,52
Center girder	0,079	9	1,78
Side girder	0,056	6,5	2,18

After obtaining the size of each section according to BKI rules, then the calculation of material requirements for making ships consisting of fiberglass, resin, and catalyst. The results of the calculation of material requirements can be seen in Table 4.

Table 4. Material Requirements for Each Section

Section	Matt weight (Kg)	Woven Weight (Kg)	Matt resin (Kg)	Woven Resin (Kg)	Catalyst (Kg)
Keel	24,3	28,3	56,7	28,3	0,85
Bottom	56,82	48,7	132,59	48,7	1,81
Side shell	112,39	96,33	262,24	96,33	3,58
Center girder	4,27	5,34	9,96	5,34	0,15
Side girder	4,58	3,93	10,7	3,93	0,14
Transom	2,75	2,35	6,41	2,35	0,08
Frame	0,74	1,11	1,73	1,11	0,02

Economic Calculation of Shipbuilding

Economic calculations are carried out by determining the price of each material to be used and then adding to the cost of ship equipment and services to build the ship. The main material costs of shipbuilding can be seen in Table 5.

Table 5. Price of Ship Body Material

Material	Price	Unit
Yukalac 157 resin	Rp.44.650.00	Kg
Catalyst	Rp.83.000.00	Kg
Fiber Matt 300 gsm	Rp.25.800.00	Kg
Woven Roving 600 gsm	Rp.30.000.00	Kg
18mm multiplex	Rp.295.000.00	Sheet

Note: Material prices are taken as of June 22, 2024

The material requirement data obtained in Table 4 is then multiplied by the material price in Table 5 which will produce Table 6 below.

Table 6. Resin Requirement Cost

Section	Qty	Unit	Unit price	Total
Keel	84,15	Kg	Rp.44.650	Rp3.757.298
Bottom	179,49	Kg	Rp.44.650	Rp.8.014.229
Side shell	206,64	Kg	Rp.44.650	Rp.9.226.476
Center girder	15,15	Kg	Rp.44.650	Rp.676.448
Side girder	14,48	Kg	Rp.44.650	Rp.646.532
Transom	8,68	Kg	Rp.44.650	Rp.387.562
Frame	2,83	Kg	Rp.44.650	Rp.126.360
AMOUNT	**511,42**	Kg	**Rp312.550**	**Rp.22.834.903**

Table 7. Cost of Catalyst Requirement

Section	Qty	Unit	Unit price	Total
Keel	0,85	Kg	Rp.83.000	Rp.70.550
Bottom	1,81	Kg	Rp.83.000	Rp.150.230
Side shell	2,08	Kg	Rp.83.000	Rp.172.640
Center girder	0,15	Kg	Rp.83.000	Rp.12.450
Side girder	0,14	Kg	Rp.83.000	Rp.11.620
Transom	0,08	Kg	Rp.83.000	Rp.6.640
Frame	0,02	Kg	Rp.83.000	Rp.1.660
AMOUNT	**5,13**	Kg	**Rp.581.000**	**Rp.425.790**

Table 8. Cost of 300gsm Matt

Section	Qty	Unit	Unit price	Total
Keel	24,3	Kg	Rp.25.800	Rp.626.940
Bottom	56,826	Kg	Rp.25.800	Rp.1.466,111
Side shell	112,39	Kg	Rp.25.800	Rp.2.899,662
Center girder	4,27	Kg	Rp.25.800	Rp.110.166
Side girder	4,58	Kg	Rp.25.800	Rp.118.164
Transom	2,75	Kg	Rp.25.800	Rp.70.950
Frame	0,74	Kg	Rp.25.800	Rp.19.092
AMOUNT	**205,856**	Kg	**Rp.180.600**	**Rp.5.311.085**

Table 9. Cost Table for 600gsm Woven Roven

Section	Qty	Unit	Unit price	Total
Keel	28,3	Kg	Rp.30.000	Rp.849.000
Bottom	48,708	Kg	Rp.30.000	Rp.1.461.240
Side shell	96,33	Kg	Rp.30.000	Rp.2.889.900
Center girder	5,34	Kg	Rp.30.000	Rp.160.200
Side girder	3,93	Kg	Rp.30.000	Rp.117.900
Transom	2,35	Kg	Rp.30.000	Rp.70.500

Frame	1,11	Kg	Rp.30.000	Rp.33.300
AMOUNT	**186,068**	Kg	**Rp.210.000**	**Rp.5.582.040**

Table 10. Cost Table of Multiplex Requirements

Section	Qty	Unit	Unit price	Total
Transom	2	sheet	Rp.295.000	Rp.590.000
AMOUNT	**2**	**sheet**	**Rp.295.000**	**Rp.590.000**

So the total cost to build the ship's body will be Rp.34.734.818

Table 11. Engine and Steering Costs

Tool name	Qty	Unit	Unit price	Total
Hangkai electric outboard 4.0	1	unit	Rp.3.637.384	Rp.3.637.384
Steering shaft	1	unit	Rp.100.000	Rp.100.000
Steering wheel	1	unit	Rp.155.000	Rp.155.000
Joystick electric	1	unit	Rp.480.000	Rp.480.000
2mm steel sling	25	meter	Rp.2.900	Rp.72.500
Battery swap	1	unit	Rp.950.000	Rp.950.000
AMOUNT				**Rp.5.394.884**

Table 12. Cost of Catch

Tool name	Qty	Unit	Unit price	Total
Fiber chair	11	unit	Rp.275.000	Rp.3.025.000
10 mm nylon rope	10	meter	Rp.5.690	Rp.56.900
AMOUNT				**Rp.3.081.900**

Table 13. Service Fee

Item	Qty	Unit	Unit price	Total
Worker wages	3	PEOPLE	Rp.125.000	Rp.375.000
Length of service	10	DAY	Rp.375.000	Rp.3.750.000
AMOUNT				**Rp.4.125.000**

All costs that have been obtained are then summed up and the total cost required to make one unit of the river cruise ship with a capacity of 11 people is Rp.47.345.602

BEP calculations are carried out by making the number of passenger realizations a variable so that different BEP durations are obtained. The variable number of passengers used is when the ship is filled to 100% capacity, 75% capacity, 50% capacity, and 25% capacity as shown in Table 14.

Table 14. BEP calculation

Variables	**% Capacity**			
	100%	**75%**	**50%**	**25%**
Trip duration	30 minutes	30 minutes	30 minutes	30 minutes
Jam Ops	480 minutes	480 minutes	480 minutes	480 minutes
Target Trip	16 trips	16 trips	16 trips	16 trips
Real Passengers per day	160 people	160 people	160 people	160 people
Ticket price	Rp.8,000	Rp.8.000	Rp.8.000	Rp.8.000
Target revenue per day	Rp.1.280.000	Rp.960.000	Rp.640.000	Rp.320.000
BEE	36.99 days	49.32 days	73.98 days	147.95 days

CONCLUSIONS

The design of the river cruise ship obtained the main size of the ship. L = 10 meters, B = 2.3 meters, H = 1.2 meters, T = 0.5 meters, Δ = 4.75 tons, The ship has 18 frames with a distance of 50cm Per frame.

The cost of making one unit of the river cruise ship is Rp.47.345.602. This cost consists of body materials, machinery, supporting equipment, and services until the ship is ready for operation. The ship will reach the BEP point in 36.9 days with 100% passenger capacity, 49.32 days at 75% passenger capacity, 73.98 days at 50% passenger capacity, and 147.95 days at 25% passenger Condition.

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