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The Design and Facility Layout of Traditional Boat-building Based on the Regression Model

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Abstract. Traditional fishing boats are used widely by fishermen in Indonesia. However, the design has not been standardized yet. Therefore, it will influence the resistance and the endurance tests. In this study, we aim to design the lines plan model of a fishing boat for the standardization of its components. The regression model is used to determine the length of the keel, the height of the boat, the length of the boat, and the width of the boat. The results show the general arrangement, lines plane design, and facility layout of traditional boats based on the regression model. This study will contribute to the business process development at the shipyard and the small craft technology.

Keywords: Design, Facility, Boat Building, Shipyard

1 Introduction

The shipbuilding industry clusters in East Java, Indonesia are mainly located in four cities, namely: Surabaya, Lamongan, Tuban, and Gresik. The majority of traditional shipyards in Lamongan build wooden boats for fishing boats. One of the challenges at traditional shipyards is the construction of fishing boats that do not comply with the standard. Then, it will impact to the resistance and endurance tests.

Previous literature study concerns on the evaluation of project management at traditional shipyard using the *S*-curve, schedule performance index, and cost performance index (Praharsi et. al., 2021); business feasibility study of traditional boatbuilding from market, economic, technical, financial, and customer needs aspects (Praharsi et. al., 2023); the sustainability of traditional boat building production process (Praharsi et. al., 2020), modeling of traditional boat building in multivariate and simple linear regressions based on the material requirement planning and the man hours needed (Praharsi et. al., 2019), the implementation of Supply Chain Operations Reference (SCOR) metrics for improving the traditional boat building supply chain performance (Praharsi, et. al., 2022), The integration of lean six sigma and resilience strategies in the maritime industry during COVID-19 disruptions (Praharsi et. al., 2021), The measurement of shipbuilding technology capability using the technometric assessment model such as technoware, humanware, infoware, and orgaware indicators (Ma'aruf et. al., 2024), The identification of critical success factors for remanufacturing and reuse of equipment in the engineer-to-order (ETO) shipbuilding industry (Alfnes et. al., 2024), the design and logistics optimization of internal material flows at ETO and Design-to-order plants

(Braglia, et.al., 2024). Nevertheless, none of them discussed about the design and facility layout of traditional boatbuilding.

Some problems exist in traditional boatbuilding namely: 1) low efficiency, 2) not aligning with the desired service speed, 3) bad propeller performance or the occurrence of cavitation, 4) the nature of boat resistance because of improper propeller size, and 5) the size of the gearbox and engine is not proper. Therefore, it is necessary to carry out a reengineering of the boat shape and its optimization. The objective of this study is to develop the design of a general arrangement and lines plane based on the regression model. Furthermore, the layout facility of used components is arranged.

2 Literature Review

2.1 Simple linear regression

The regression equation represents the linear relationship between two variables. Simple linear regression involves one independent variable. The general form of simple linear regression is as follows (Kutner et al., 2008):

$$\boldsymbol{\hat{y} = a + bx} \tag{2.1}$$

where:
$\hat{y}$: the estimation of y value for each chosen x value
a: the intercept of y
b: the gradient
x: independent variable

2.2 Facility layout

Facility layout is the arrangement of machinery, equipment, and other resources within a facility to optimize the flow of materials, improve operational efficiency, and ensure safety and flexibility. The objective of facility layout is to design an effective layout that minimizes transportation time and costs, reduces handling and delays, and enhances productivity. Several types of layouts are process layout, product layout, cell layout, and fixed-position layout. In this research, we used a fixed-position layout which keeps the fish cargo space stationary while workers, materials, and equipment move around it. Some considerations in facility layout are the flow of materials, space utilization, safety, flexibility, and ergonomics.

2.3 Lines plane

Lines plan is a basic outline plan description of a ship to plan the initial shape and size of a ship before construction is carried out. This lines plan can project the output shape of the ship that will be produced, where the lines plan includes pictures and lines that visualize the contour of the ship in each cross-section, longitudinal section, and vertical map. The lines plan is also the basis for design calculations and determines the dimensions and physical shape of the ship. The following are the main functions of the lines plan: (a) as design planning and initial dimensional calculations; (b) to determine weight distribution and determine stability; (c) help visualize the shape of the hull; (d) as a basis for calculating ship capacity and volume; (d) ship construction guidelines.

2.4 General arrangement

General arrangement design must consider conformity with the lines plan that has been developed, compliance with DWT, capacity, and speed required. General arrangements are used for several purposes, not just to show the type of ship and its features. Shipyards also used for making initial calculations of shipbuilding costs as well as a basis for making detailed drawings.

3 Literature Review

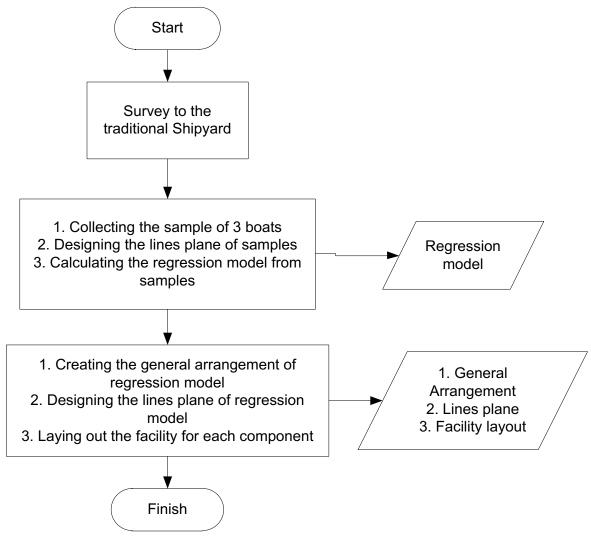

Fig. 1 Research Methodology

Based on Figure 1, the research is started by doing survey to several traditional shipyards in Lamongan. We collected 3 boats that have 'Perahu' type and measured their length, breadth, height, and LOA. Perahu type has a taper shape on the boat's prow. The boat size is around 30 GT. Subsequently, the lines plane of each boat is drawn and the regression model is calculated. After the size of a regression model is retrieved, we create the general arrangement and the lines plane. Finally, the facility layout is drawn including the components. Software used are Maxsurf, Lumion, Autocad, Fusion 360, Microsoft Excel, and Rhinocheros.

4 Data Collection

We collect the data from 3 traditional boats as the input for regression model, namely Semot Ireng, Wirausaha, and Mekarjaya. The lines plane and the principal dimension are shown in Figures 2, 3, and 4.

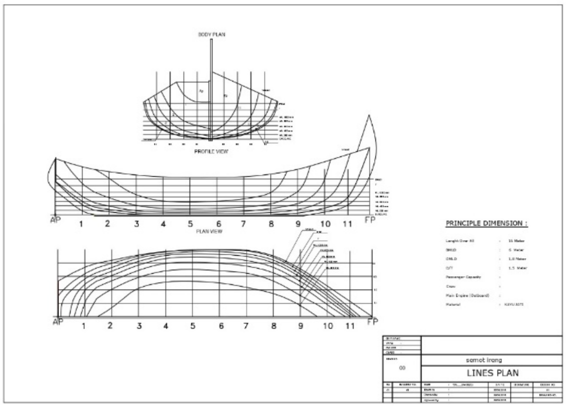

Fig. 2 Lines plan of Semot Ireng

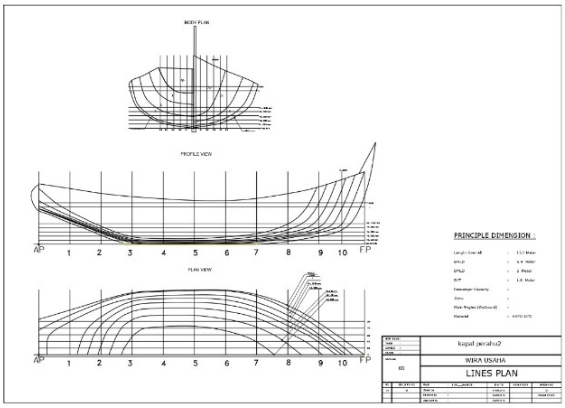

Fig. 3 Lines plan of Wirausaha

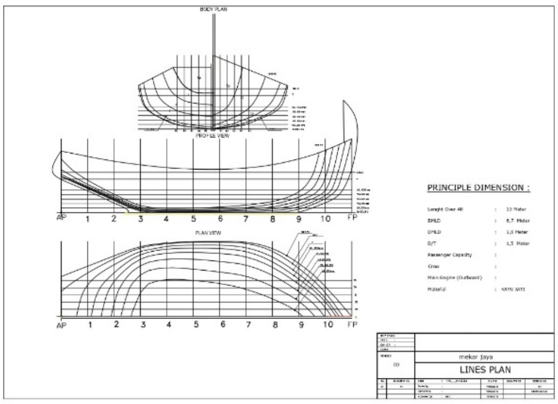

Fig. 4 Lines plan of Mekar Jaya

Figures 2-4 show lines plane from Semot Ireng, Wirausaha, and Mekar Jaya boats as references for comparison. Subsequently, we process it into the linear regression equation in order to obtain the new model with a size of approximately 30 GT.

5 Data Collection

5.1 Numerical Results

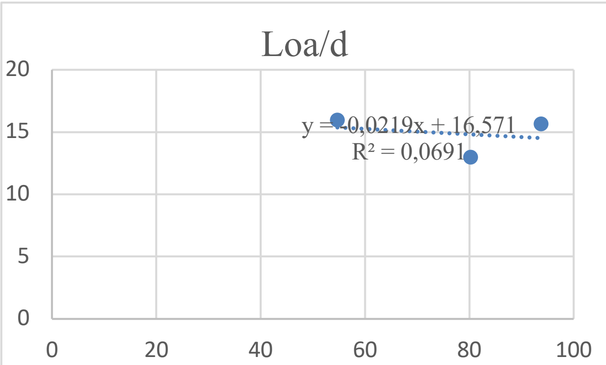

Fig. 5 The regression model of LOA / Displacement

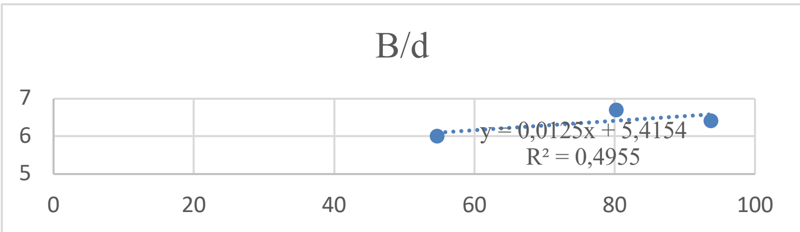

Fig. 6 The regression model of breadth / Displacement

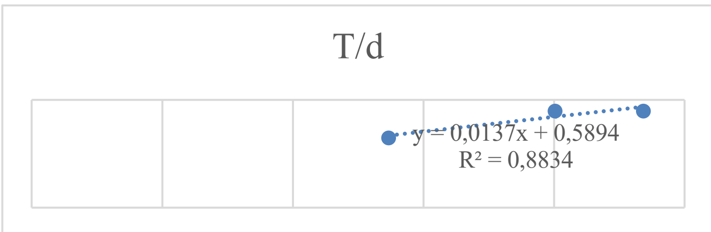

Fig. 7 The regression model of Draft / Displacement

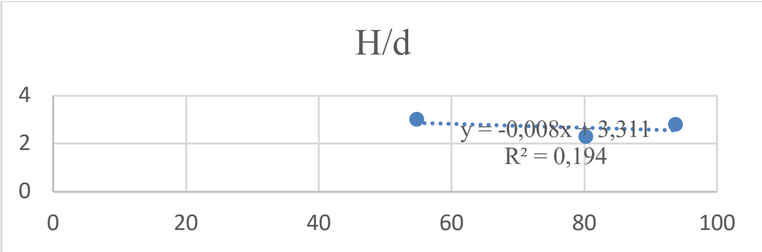

Fig. 8 The regression model of height / Displacement

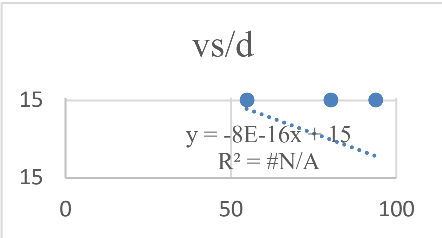

Fig. 9 The regression model of speed / Displacement

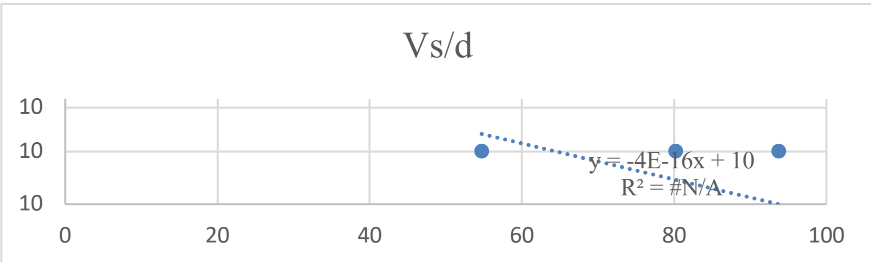

Fig. 10 The regression model of speed / Displacement

Figure 5 shows the linear regression used to obtain the new boat LOA with LOA/displacement.

$$
\begin{aligned}
LOA &= 0.0219x + 16.571 \\
&= 0.0219(30) + 16.571 \\
&= 17.23 \text{ m}
\end{aligned}
$$

(x is the Displacement which will be achieved i.e. 30 Gross tonnage)

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, a new LOA of 17.23 meters was obtained.

Figure 6 shows the linear regression used to obtain the new boat width with Breadth/Displacement.

$$
\begin{aligned}
B &= 0.0125x + 5.4154 \\
&= 0.0125\,(30) + 5.4154 \\
&= 5.79 \text{ m}
\end{aligned}
$$

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, the new breadth is 5.79 meters.

Figure 7 shows the linear regression used to obtain the new boat's draft with T/Displacement.

$T = 0.0137x + 0.5894$
$= 0.0137(30) + 0.5894$
$= 1.00$ m

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, the new T is 1.00 meters.

Figure 8 shows the linear regression used to obtain the new boat height with H/Displacement.

$H = 0.008x + 3.311$
$= 0.008(30) + 3.311$
$= 3.55$ m

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, the new H is 3.55 meters.

Figure 9 shows the linear regression used to obtain the new boat height with Vs Max/Displacement.

Vs Max $= 0.0001x + 15$
$= 0.0001(30) + 15$
$= 15$ knot

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, the new Vs max is 15 knots.

Figure 10 shows the linear regression used to obtain the service speed of a new boat with Vs service/Displacement.

Vs service $= 0.0002x + 10$
$= 0.0002(30) + 10$
$= 9.99$ m

From the regression that has been carried out using 3 comparison boats, namely Semot Ireng, Wirausaha, Mekar Jaya, and from the results of calculations using the linear regression method, the new Vs service is 9.99 meters.

Based on the regression calculation for 3 boats, the results for the new boats have LOA, Breadth, T, Vs service, Vs Max, and height as summarized in Table 1.

Table 1 The results of regression for a new boat

New LOA	:	17.23 m
New B	:	5.79 m
New T	:	1.00 m
New H	:	3.55 m
Vs Max	:	15.00 knot
Vs service	:	9.99 knot

5.2 Graphical Results

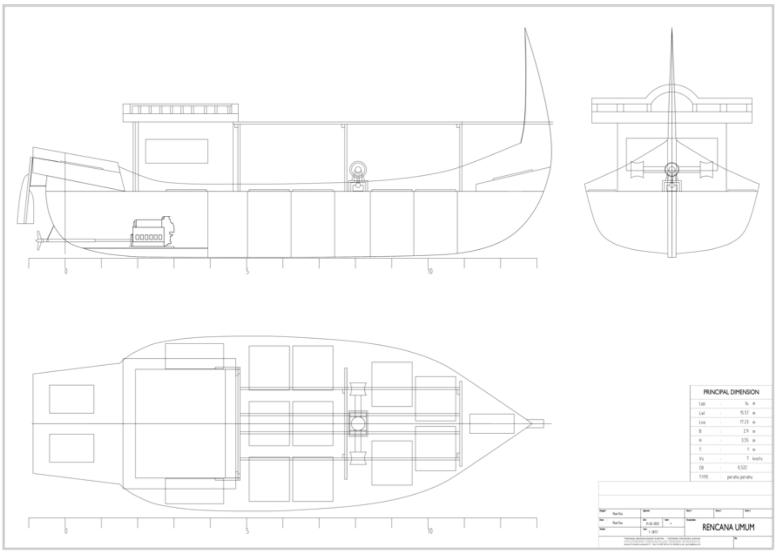

Fig. 11 General arrangement of regression model

Figure 10 shows the general plan of the new boat regression results

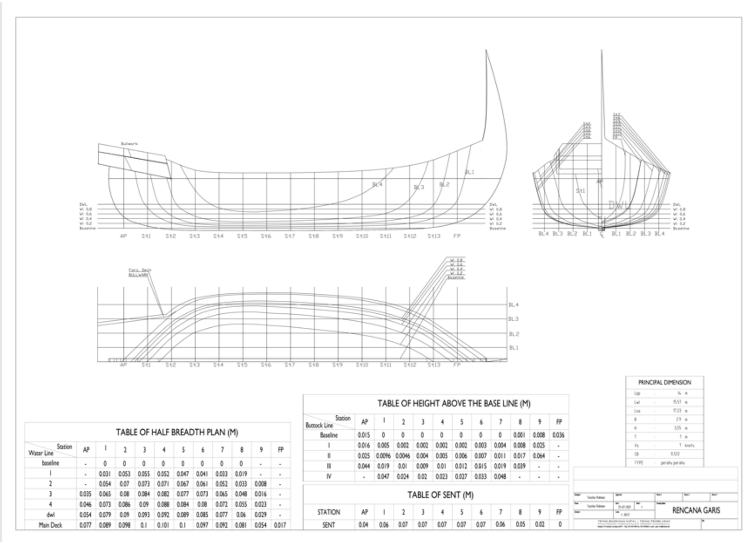

Fig. 12 Lines plane of regression model

Figure 11 shows the lines plan from the new boat regression results

5.3 The facility layout

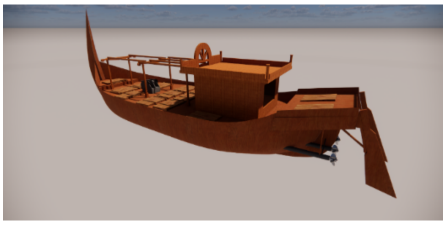

Fig. 13 Facility layout at the left side

Fig. 14 Facility layout at the right side

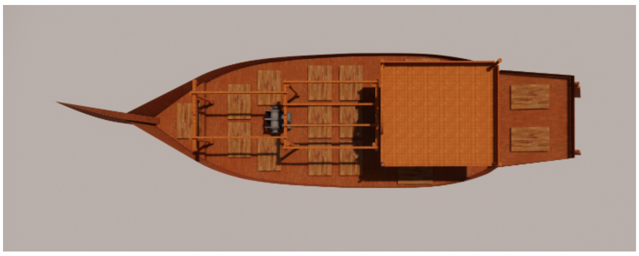

Fig. 15 Facility layout at the top

Fig. 16 Facility layout at the front

Fig. 17 Facility layout at the back

Figures 12, 13, 14, 15, and 16 show the 3D visual results of the boat from the new regression which shows the equipment and parts of the boat as seen in the fish storage section and superstructure. The stern of the boat shows the 2 rudders of the boat and the propulsion using 3 ship propellers. In this 3D creation process, Maxsurf and Lumion software were used.

6 Conclusion

We have discussed the general arrangement, lines plane design, and facility layout of traditional boats based on the regression model. It can be inferred that this model can be used for the standardization of traditional fishing boatbuilding considering the test of stability, resistance, and endurance. The facility layout can maximize the boat's cargo space. The new designs might affect the fuel energy consumption, propeller, and speed performances. Thereby, it contributes to the sustainability of boatbuilding practices.

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