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Standardization of Man-Hours Requirements in Multi-Years Projects in the Indonesian Shipyard Industry

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Abstract: The shipbuilding industry plays a vital role in international trade, with ship construction being a complex technical process requiring skilled labor. This study aims to analyze and develop a standardized estimation model for man-hour (MAN- HOURS) requirements in the execution of multiyear projects within the shipyard industry, specifically at PT DEF. Based on historical data from the past 10 years encompassing 16 shipbuilding and general engineering projects, the research employs a quantitative descriptive approach using multiple linear regression analysis. Key variables include Project Duration (months), Contract Price (in million Rupiah), and Ship Weight (in tons), with man-hours as the dependent variable. The results of the classical assumption tests—normality, multicollinearity, and heteroscedasticity—indicate that the regression model meets the necessary statistical assumptions. Furthermore, hypothesis testing reveals that the variables of Contract Price and ship weight significantly influence the man-hour requirements, whereas project duration does not show a statistically significant impact. The resulting regression model provides a reliable basis for predicting labor requirements in similar future projects. This standardization is expected to improve workforce planning accuracy, enhance operational efficiency, and offer practical recommendations for optimizing multiyear projects in the shipbuilding industry.

Keywords: *Man-Hour Requirements, Project Duration, Standardization, Cost Efficiency, Shipyard Industry.*

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I. INTRODUCTION

The shipbuilding industry plays a pivotal role in global trade and economic development, involving intricate and labor-intensive processes that require precise coordination and skilled human resources. In multiyear shipbuilding projects, accurate estimation and allocation of Man-Hours is critical to ensure timely completion and cost efficiency. Man-Hours refers to the total labor time needed to complete tasks within a project, and its calculation is influenced by various factors, including project complexity, ship type, and resource allocation [1]. At PT DEF, historical data over the past decade reveals a wide variation in Man-Hours requirements across different types of new build projects, particularly between complex warships such as Landing Dock vessels and simpler ships like Tug Boats. These discrepancies highlight the need for a standardized framework to improve the accuracy and effectiveness of Man-Hours planning.

This study aims to fill that gap by examining the factors that influence Man-Hours disparities across multiyear shipbuilding projects at PT DEF. Specifically, it seeks to identify the most significant determinants of Man-Hours needs, and to develop a predictive model linking Man-Hours with variables such as project type, Ship Weight, and duration. Using a decade's worth of project data, the study applies quantitative analysis and predictive modeling to propose a standardized Man-Hours estimation framework. In doing so, it contributes not only to PT DEF's operational efficiency but also provides a practical reference for other shipyards in optimizing workforce planning and improving project performance [5].

II. LITERATURE REVIEW

Multiyear project management in the shipbuilding industry requires a structured and standardized approach due to the technical complexity and long project duration. Planning, execution, and control are essential to ensure that projects meet the defined specifications, budget, and timeline [6]. In ship construction projects, the effective integration of technology and labor productivity—measured in Man- Hours—is key to successful delivery [7].

Standardization of labor hours plays a vital role in maintaining consistency and improving planning accuracy. It minimizes unnecessary variation and supports better

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forecasting of manpower needs [8]. Optimization methods, such as predictive modeling and data-driven simulations, are employed to align labor demands with project characteristics like duration, Contract Price, and ship weight [9]. The integration of standardization and optimization enhances project efficiency and addresses the operational challenges in long-term shipyard projects [10].

Regression analysis—particularly multiple linear regression—is a valuable statistical tool used to build estimation models for Man-Hour requirements based on historical data. Independent variables such as project duration, Contract Price, and ship LWT can be used to estimate total labor hours [11]. This approach allows project managers to create standardized references that can be flexibly applied to different shipbuilding projects with similar profiles [12].

Minitab software serves as an effective platform for conducting regression analysis in multiyear shipbuilding projects. It offers comprehensive features including significance testing, R-squared values, and residual plots, which are crucial for evaluating model quality [13]. Minitab also facilitates quick and accurate data processing and presents results in professional reports, making it ideal for technical documentation and decision support [14]. Its ease of use and analytical power make it a preferred tool in industrial engineering and project management research.

III. METHODS

The approach used is quantitative descriptive, utilizing statistical analysis and multiple linear regression methods. The analysis was conducted using descriptive statistical techniques, regression, and Minitab software to perform the multiple linear regression. The variables in this study include Man-Hour requirements as the independent variables and project duration, contract price & ship weight as the dependent variable. The study population comprises all Multiyears projects at PT DEF over the past 10 years, with selected samples from relevant projects that provide sufficient data. This study aims to develop more efficient and realistic Man- Hour requirement standards and to provide practical recommendations for project management. The results of the analysis serve as a foundation for standardization and the formulation of research conclusions.

IV. RESULTS AND DISCUSSION

The quantitative data analysis in this study aims to identify the relationship between numerical variables that influence man-hour requirements in shipbuilding projects. A multiple linear regression approach is used to measure the simultaneous effect of three independent variables—project duration, Contract Price, and ship weight—on the dependent variable, namely man-hour requirements. This analysis, conducted using Minitab software, is expected to produce an objective and statistically measurable predictive model that can serve as a reference for estimating human resource needs in future projects.

The initial data set consists of 15 shipbuilding and engineering projects undertaken by PT DEF over the past 10 years, covering various types such as landing dock ships, patrol ships, merchant vessels, and general engineering projects. Each project includes four key variables: duration, Contract Price, ship weight, and man-hour requirements (Table 1). Significant variations across these variables indicate a clear correlation with labor needs. The use of multiple linear regression is particularly relevant in project management and industrial engineering, as it not only quantifies the impact of each factor but also aids in workforce planning and supports the standardization of man-hour requirements in multi-year shipbuilding projects.

Table 1 Initial Data of PT DEF Multiyears Project Regression for the Last 10 Years

NO	PROJECT	X1 (DURATION, MONTHS)	X2 (PRICE, BILLION IDR)	X3 (WEIGHT LWT, TON)	Y (MAN HOUR)	CLASS
1	SSV 1	24	517	4678	1005943	LANDING DOCK CLASS
2	SSV 2	36	517	4678	1236936	
3	LPD 3	23	736	4099	1010648	
4	HOSPITAL SHIP 1	32	765	4569	1147955	
5	HOSPITAL SHIP 2	30	765	4569	1457185	
6	PATROL BOAT 1	27	125	350	441498	PATROL BOAT CLASS
7	PATROL BOAT 2	27	125	350	300531	
8	PATROL BOAT 3	30	125	350	350326	
9	PATROL BOAT 4	24	150	350	282036	
10	PATROL BOAT 5	24	307	350	326915	
11	PATROL BOAT 6	27	307	350	300532	
12	TUGBOAT	16	51	326	145010	MERCHANT SHIP
13	EPCI BANOWATI	37	394	2675	535436	GENERAL ENGINEERING
14	BMPP 1	26	996	4250	148468	
15	BMPP 2	25	996	4250	253827	

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A. Classical Assumption Test

Before proceeding to the multiple linear regression analysis, a series of classical assumption tests were conducted to ensure that the model met the basic statistical requirements. The tests conducted included normality, multicollinearity, and heteroscedasticity tests. The normality test using the Probability Plot showed that the residual model was normally distributed (P-Value > 0.05), which was indicated by data points approaching the diagonal line. This indicates that the model meets the residual normality requirements, which are important so that parameter estimates are not biased and valid for statistical inference.

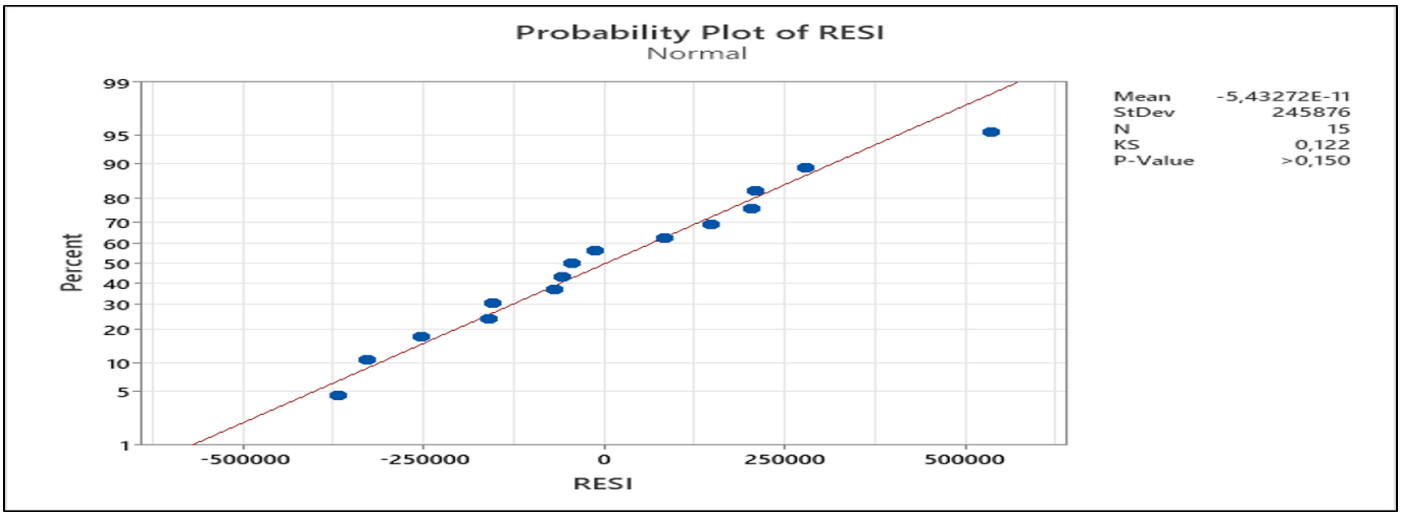

Fig 1 P-Plot Diagram

Furthermore, the multicollinearity test was conducted by calculating the Variance Inflation Factor (VIF) value for each independent variable: project duration (X1), contract price (X2), and ship weight (X3). The results showed that all VIF values were below the threshold of 10 (the highest was 4.78 for the weight variable), which means that there was no significant multicollinearity between the independent variables. Thus, each independent variable can be considered to have an independent influence on the need for man-hours, making the regression model more stable and interpretative.

Table 2 Regression Test Result

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	75155	417805	0,18	0,861	
X1 (DURATION)	11926	15277	0,78	0,451	1,19
X2 (PRICE)	-1128	476	-2,37	0,037	4,40
X3 (WEIGHT,LWT)	295,9	78,9	3,75	0,003	4,78

The heteroscedasticity test was conducted through the analysis of the residual plot against the predicted values (fitted values). The results show no specific pattern in the residual distribution — the points are randomly scattered around the zero horizontal line. This indicates that the residual variance is constant (homoscedasticity), and no significant indication of heteroscedasticity is found. With the fulfillment of these three classical assumptions, the multiple linear regression model can be said to be valid and suitable for further analysis and preparation of man-hour requirements standards in multi-year projects.

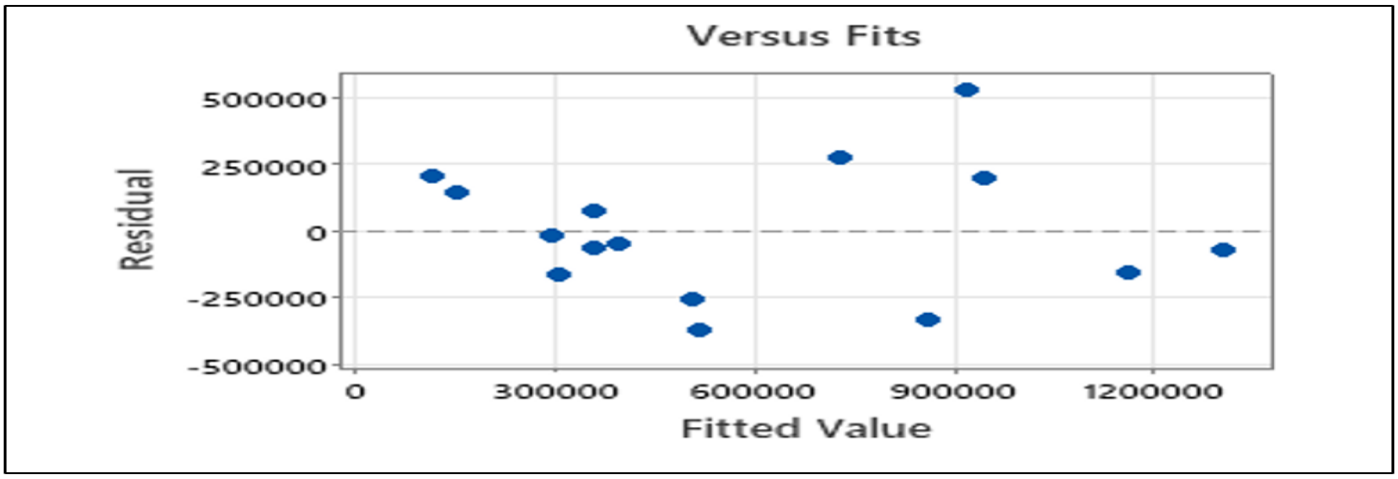

Fig 2 Plot Residual Versus Fitted Value

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B. Multiple Linear Regression Test

Hypothesis testing is used to determine whether there is a significant influence of the independent variables on the dependent variable. In this context, testing was carried out on three independent variables, namely duration (X1), contract price (X2), and ship weight (X3), on Man-Hours (Y). The results of the regression test showed that variables X2 (Price) and X3 (ship weight) have a significant influence on Y because the P-Value values are 0.037 and 0.003 (<0.05), respectively, while X1 (Duration) is not significant (P-Value = 0.451). Thus, only price and ship weight are proven to contribute statistically to labor requirements (Man-Hours), while duration does not have a significant effect. Analysis of Variance (ANOVA) was conducted to see the simultaneous influence of the three variables on Man-Hours. The results of the ANOVA showed (Table 3) that the P-Value for the entire regression model was 0.004 (<0.05), which means that the model as a whole is significant.

This means that the combination of the variables Duration, Price, and ship weight together have an effect on the value of Man-Hours. Although partially Duration is not significant, in the combined model the three variables still contribute to changes in the Man-Hours value. The F value of 8.25 supports the conclusion that the model is able to explain variations in the data well. The coefficient of determination (R^2) of 69.24% indicates that most of the variations in Man- Hours can be explained by the variables Duration, Price, and Ship Weight. The remaining 30.76% is explained by other factors outside the model (Table 4). By using the regression coefficient value, the equation is obtained (Figure 2). The interpretation of this equation shows that increasing ship weight and work duration will increase labor requirements, while increasing prices tend to reduce Man-Hours requirements, possibly due to higher efficiency or use of technology.

Table 3 Analysis of Variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	1,90495E+12	6,34983E+11	8,25	0,004
X1 (DURATION)	1	46888754013	46888754013	0,61	0,451
X2 (CONTRACT PRICW)	1	4,32722E+11	4,32722E+11	5,62	0,037
X3 (LWT)	1	1,08188E+12	1,08188E+12	14,06	0,003
Error	11	8,46368E+11	76942533684		
Lack-of-Fit	10	8,36432E+11	83643202298	8,42	0,263
Pure Error	1	9935847545	9935847545		
Total	14	2,75132E+12			

Table 4 Coefficient of Determination

S	R-sq	R-sq(adj)	R-sq(pred)
277385	69,24%	60,85%	41,04%

$$Y \text{ (Man-Hours)} = 75155 + 11926\ X1 - 1128\ X2 + 295{,}9\ X3$$

Fig 3 Regression Equation

V. CONCLUSION

Based on the results of the data analysis that has been carried out, it can be concluded that the multiple linear regression model built in this study successfully identified the main factors that influence the need for man-hours in shipbuilding projects. Of the three independent variables tested — project duration, contract price, and ship weight — only ship price and weight were proven to have a statistically significant influence on labor requirements, both partially and simultaneously. The coefficient of determination (R^2) value of 69.24% indicates that the model has a fairly good predictive ability in explaining variations in Man-Hours requirements based on the three variables. Thus, the results of this study provide a strong quantitative basis for more efficient human resource planning in the shipbuilding industry, and can be used as a reference in standardizing man-hour requirements for multi-year projects in the future.

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