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Research Article

The Effect of Mobility Costs and Heavy Equipment Maintenance Costs on Rental Prices at PT Sarana Baja Perkasa

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Abstract
Operational efficiency and cost management are crucial determinants of corporate sustainability in the heavy equipment rental industry. This study aims to analyze the partial and simultaneous effects of mobility costs and maintenance costs on the operational performance of heavy equipment at PT Sarana Baja Perkasa. Using a quantitative approach and an explanatory research design, a causal study examining the effect of the independent variables on the dependent variable, data were collected from 62 operational and engineering personnel using a saturated sampling method, complemented by historical financial and operational records. Data were analyzed using Multiple Linear Regression, along with classical assumption tests, partial t-tests, simultaneous F-tests, and the coefficient of determination (R^2). The empirical findings indicate that mobility costs have a positive and significant effect on heavy equipment operations (β_1=0.342, $p<0.05$). Maintenance costs also exhibit a strong positive and significant impact (β_2=0.518, $p<0.05$). Simultaneously, mobility costs and maintenance costs significantly influence operational performance (F=48.612, $p<0.05$), accounting for 62.2% of the total variance (R^2=0.622, Adjusted R^2=0.609). These results confirm that systematic mobility planning and proactive maintenance strategies are vital for minimizing equipment downtime and maximizing equipment availability. The study contributes to Asset Life Cycle Theory by providing empirical evidence on logistics and maintenance synergy in archipelago-based infrastructure projects.

Keywords: Asset Life Cycle, Equipment Availability, Heavy Equipment Operations, Maintenance Costs, Mobility Costs.

1. Introduction

The heavy equipment rental industry plays a highly strategic role in supporting the sustainability of various sectors of national development, such as construction, mining, logistics and civil infrastructure. From an operational management perspective, heavy equipment is not merely viewed as a technical support tool, but as high-cost productive assets (capital-intensive assets) that must be managed efficiently to achieve optimal operational performance (Febrianto et al., 2025). Effective heavy equipment management aims to increase productivity, optimize mechanical availability, and minimize unplanned operational downtime (Guzman, 2023).

Within the framework of Total Cost of Ownership (TCO), the entire structure of expenditure incurred throughout the asset's life cycle, from mobilization, operation at the worksite, to routine maintenance, must be managed in an integrated manner so as not to erode the company's profitability (Nagle et al., 2023). However, operational realities in Indonesia often present complex technical and logistical challenges. Indonesia's archipelagic geography, coupled with limited infrastructure in remote areas, frequently leads to surges in mobility costs and increases the risk of unit damage due to extreme working conditions (Turbaningsih, 2022).

At PT Sarana Baja Perkasa, this phenomenon is reflected in fluctuations in monthly operational costs that do not always correlate linearly with improvements in unit performance. For example, internal data for the period July-December 2025 shows that in October, mobility costs peaked at Rp165,000,000 and maintenance costs at Rp98,000,000; however, equipment availability actually fell to its lowest level of 79 per cent, with productivity at 195 tons per day. Conversely, in September, with mobility costs of Rp138,000,000 and maintenance costs of Rp83,000,000, equipment availability reached 86 per cent and productivity soared to 217 tons per day.

This mismatch indicates the presence of reactive maintenance practices and wastage of travel time that has not yet been properly quantified. From an academic perspective, this situation highlights a research gap. Previous research by Yin et al. (2023) tended to focus on the macro-level rental supply chain without evaluating the costs of physical mobility in extreme terrain. On the other hand, Deng et al. (2025) emphasized maintenance optimization within leasing systems, but have not empirically tested the simultaneous interaction between mobility and maintenance costs on operational performance indicators in Indonesian leasing companies.

Taken together, these two streams of research leave a combined gap unaddressed: the interplay between the physical logistics of moving equipment and the technical reliability of maintaining it, evaluated jointly within a single operational performance model. Therefore, this study aims to fill these academic and practical gaps by empirically testing, analyzing and validating the partial and simultaneous effects of mobility costs and maintenance costs on the operation of heavy machinery at PT Sarana Baja Perkasa, addressing whether mobility costs affect this operation, whether maintenance costs affect it, and whether the two costs simultaneously affect it.

2. Literature Review

2.1. Theoretical Framework

2.1.1. Asset Life Cycle Theory and Total Cost of Ownership (TCO)

This research is based on the Asset Life Cycle Theory, combined with the concept of Total Cost of Ownership (TCO). The Asset Life Cycle Theory posits that every high-cost capital asset, such as a piece of heavy machinery, systematically progresses through four main phases. The first is Acquisition (Procurement), which involves planning technical specifications and purchasing assets. The second is Operation (Utilization), which involves operating the unit to generate economic value for the company. The third is Maintenance (Maintenance/Care), which involves maintenance and repair activities to maintain mechanical reliability. The fourth is Disposal (Disposition/Replacement), which involves the sale or disposal of a unit when its operating costs have exceeded its economic benefits (Febrianto et al., 2025).

In the context of operational management in the heavy equipment hire sector, efficiency is not only measured by rental income, but also by the optimization of all costs incurred throughout the asset's life cycle (Life Cycle Costs). Controlling financial allocation during the utilization and maintenance phases directly determines the level of sustainability of the equipment's technical functionality. An imbalance in the allocation of logistics and maintenance costs will accelerate the moral/technical depreciation of the unit and lead to high levels of downtime (Nagle et al., 2023).

Table 1. Asset Life Cycle Stages, Related Research Variables, and Their Implications for Heavy Equipment Operations

Stages of the Asset Life Cycle	Description & Key Activities	Related Research Variables	Implications for the Operation of Heavy Equipment (Y)
Acquisition (Procurement)	Planning of technical specifications, requirements analysis, and procurement of new or hired heavy equipment.	(Post-Operational Phase)	Determining the initial capacity limits, baseline fuel efficiency and potential reliability of the engines.
Utilization (Operation & Mobilization)	Operation of equipment at work sites and the physical distribution or relocation of equipment between project sites.	Mobility Costs (X1)	Efficient logistics planning minimizes travel downtime and ensures units are ready on time.
Maintenance (Preventive & Corrective)	Carrying out regular routine maintenance, replacing spare parts, and repairing mechanical faults.	Maintenance Costs (X2)	Adequate maintenance budget support maintains mechanical availability and minimizes unscheduled downtime.
Disposal (Disposition & Replacement)	Disposal, sale, or replacement of assets when operating costs have exceeded their economic useful life.	(Post-Operational Phase)	Optimizing the total cost of ownership (TCO) to maintain the overall efficiency of the fleet.

Source: Authors' compilation

2.1.2. Heavy Equipment Operation (Y)

Heavy equipment operations are defined as an integrated working ecosystem that reflects the level of effectiveness, technical reliability and efficiency of capacity utilization in supporting the achievement of project targets without breaching safe operating limits (Febrianto et al., 2025; Guzman, 2023). Heavy equipment operational indicators are grouped into four main dimensions (Purnomo, 2025). The first is Mechanical Availability (MA), the percentage of time a unit is ready to operate without technical faults. The second is Minimization of Downtime, the ability of an operational system to minimize unscheduled downtime. The third is Hour Meter Efficiency, the quantity of work output (e.g., tonnage transported or volume excavated per hour) produced in accordance with standard target ratios. The fourth is Compliance with Safe Load Limits, the reliability of unit operation within technical parameter limits to prevent material fatigue.

2.1.3. Mobility Costs (X1)

Mobility costs are the cumulative total of both planned and incidental logistics expenditure incurred by a company to move heavy equipment units from a base (pool/workshop) or a previous project site to a new project site (Turbaningsih, 2022). Poor mobility management has the potential to cause travel downtime and premature technical damage due to jolts or incorrect handling during transport.

The dimensions and measurement indicators for Mobility Costs (X1) include: Physical Transport Costs, which are expenditures on the hire of specialized transport vehicles (towing or low-bed trailers); Mobilization Fuel Costs, which are fuel costs specifically allocated for the unit's relocation process; Loading and Unloading Costs, which are operational expenditures on rigging and positioning of equipment; and Permit and Escort Costs, which are administrative charges for cross-regional travel, road tonnage permits, and incentives for road escort fleets.

2.1.4. Maintenance Costs (X2)

Maintenance costs are the financial allocations invested on a regular basis to maintain, restore or improve the physical and mechanical condition of heavy equipment units so that they remain at an optimal level of performance (Alfadhlani et al., 2025; Deng et al., 2025).

The dimensions and measurement indicators for Maintenance Costs (X2) include: Preventive Maintenance, which is expenditure on scheduled maintenance, such as oil changes, filter replacements, greasing, and routine inspections; Spare Parts Replacement, which is costs for wearing parts and major components; Corrective/Breakdown Maintenance, which is funding allocated for emergency repairs when technical failures occur in the field; and Technician and Workshop Service Costs, which are costs associated with mechanical expertise, overhaul repairs, and technical calibration equipment.

2.2. Hypothesis Development

2.2.1. The Effect of Mobility Costs on Heavy Machinery Operations (H1)

In theory, the process of transporting heavy machinery involves significant technical risks. Well-planned mobility funding ensures that transport is carried out using suitable low-bed fleet facilities, pre-surveyed routes, and adequate escorts. Optimally allocated mobility costs prevent delivery delays and minimize structural damage or electrical faults caused by excessive vibrations during transit (Turbaningsih, 2022; Su et al., 2024).

Consequently, the availability of an adequate mobility budget is directly proportional to the readiness of the equipment upon arrival at the work site. Based on this argument, the first hypothesis is formulated as follows:

H1: Mobility costs have a positive and significant effect on the operation of heavy machinery.

2.2.2. The Impact of Maintenance Costs on Heavy Equipment Operations (H2)

The implementation of Reliability-Centered Maintenance (RCM) requires sufficient financial resources to carry out preventive maintenance interventions in a disciplined manner. The allocation of adequate maintenance costs enables the early detection of component failure (incipient failure detection) before it leads to cracks or fatal failures in the hydraulic system (Alfadhlani et al., 2025).

Regular maintenance expenditure effectively reduces unscheduled downtime, maintains Mechanical Availability (MA) above the industry standard threshold (> 85 per cent), and optimizes the productivity of units in the field (Purnomo, 2025; Suartika et al., 2024). Therefore, the second hypothesis is formulated as follows:

H2: Maintenance costs have a positive and significant effect on the operation of heavy machinery.

2.2.3. The Simultaneous Effect of Mobility and Maintenance Costs on Heavy Equipment Operations (H3)

Optimal heavy equipment operations cannot be achieved by relying on just one aspect, logistics or maintenance, alone. Well-maintained heavy equipment will not provide economic added value if it is held up by delays in mobilization logistics. Conversely, a rapid and timely mobilization process will be in vain if the unit suffers engine failure at the work site due to neglect of routine maintenance (Wattimena & Witjaksana, 2023).

The integrated control of mobility costs (upstream chain) and maintenance costs (downstream chain) forms operational resilience, which ensures the achievement of the company's production targets. Based on this comprehensive line of reasoning, the third hypothesis is formulated:

H3: Mobility costs and maintenance costs simultaneously have a significant effect on the operation of heavy machinery.

2.3. Theoretical Framework

The conceptual framework of this study illustrates the causal relationship between the independent variables, namely Mobility Costs (X1) and Maintenance Costs (X2), and the dependent variable, namely Heavy Equipment Operations (Y).

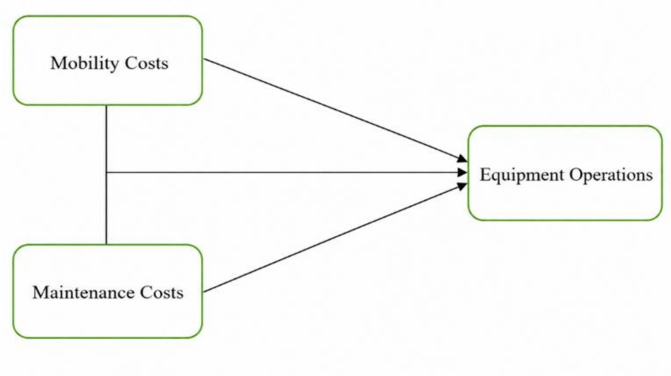

Figure 1. Conceptual Framework
Source: Authors' compilation

Explanation of the Conceptual Framework:

A. Path H1 (Partial): Tests the extent to which the efficiency of mobility cost allocation (X_1) directly contributes to ensuring the operational readiness and waiting time of units (Y) at the project site.

B. Path H2 (Partial): Tests the extent to which the level of investment in maintenance costs (X_2) directly contributes to a reduction in downtime and an increase in the mechanical availability of heavy machinery (Y).

C. Path H3 (Simultaneous): To examine the combined effect of mobility costs (X_1) and maintenance costs (X_2) on the successful achievement of operational efficiency of heavy machinery (Y) at PT Sarana Baja Perkasa.

3. Methods

3.1. Research Design, Location and Timeframe

This study employs a quantitative approach with an explanatory research design, or a study of causality. This approach was chosen to analyze and demonstrate the cause-and-effect relationship between the independent variables, namely Mobility Costs (X_1) and Maintenance Costs (X_2), and the dependent variable, namely Heavy Equipment Operations (Y).

This study was conducted at the Tangerang Branch Office of PT Sarana Baja Perkasa, located within the company's main operational area for logistics and heavy equipment hire. This location was selected due to the high intensity of fleet mobilization and unit maintenance activities in the region. The research period lasted 14 months, from February 2025 to March 2026, covering the stages of instrument development, field data collection, and statistical data processing. The July-December 2025 period referenced in the Introduction represents the window of historical operational and financial records analyzed as secondary data, while the full 14 months also encompasses the preceding stage of questionnaire design and instrument testing and the subsequent stage of data processing and analysis using SPSS.

3.2. Population, Sample and Sampling Techniques

The population in this study comprises all personnel directly involved in the decision-making chain for logistics, technical maintenance and the operation of heavy machinery at the Tangerang Branch Office of PT Sarana Baja Perkasa. This population consists of operational management staff, technical/mechanical teams, site supervisors and actively registered heavy machinery operators, totaling 62 individuals.

The sampling technique used was the Saturation Sampling Technique (Census). This technique involves selecting the entire population as the research sample without any exclusions (N=62). A census was chosen because the population size was manageable (< 100 people) and to eliminate sampling error, thereby ensuring the research results have a very high level of representativeness and precision.

3.3. Types and Sources of Data

3.3.1. Primary data

Data obtained directly from research respondents through the distribution of a structured questionnaire. The questionnaire measures respondents' perceptions of the variables of mobility costs, maintenance costs and the operational success of heavy machinery. The questionnaire instrument uses a 5-point Likert scale, with a score range as follows: a score of 1 indicates Strongly Disagree (STS), a score of 2 indicates Disagree (TS), a score of 3 indicates Neutral (N), a score of 4 indicates Agree (S), and a score of 5 indicates Strongly Agree (SS).

3.3.2. Secondary Data

Supporting data obtained from PT Sarana Baja Perkasa's internal documents during the observation period. Secondary data includes summaries of unit mobilization costs, workshop maintenance and repair logbooks, machine operating hour records (hour meters), and reports on Mechanical Availability (MA) and unit downtime.

3.4. Operationalization of Variables

The operationalization of variables is necessary to translate theoretical concepts into empirical indicators that can be measured quantitatively. Details of the operationalization of variables are presented in Table 2 below:

Table 2. Operationalization of Research Variables

Variable	Operational Definition	Indicator	Measurement Scales
Heavy Equipment Operations (Y) (Dependent Variable)	The performance and operational effectiveness of heavy machinery units in meeting project targets without any significant technical issues.	1. Equipment availability rate (Mechanical Availability / MA) 2. Minimizing downtime (unscheduled downtime) 3. Achievement of daily productivity targets (Hour Meter) 4. Compliance with safe workload limits (safe operating limit)	Likert scale (1-5)
Mobility Costs (X1) (Dependent Variable)	The total accumulated financial costs incurred in moving heavy machinery between project sites or from the depot.	1. Cost efficiency in cargo transport (towing/lowbed) 2. Affordability of fuel allocations for mobilization journeys	Likert scale (1-5)

Variable	Operational Definition	Indicator	Measurement Scales
		3. Costs relating to track licensing and escort services 4. Minimizing travel obstacles/disruptions	
Maintenance Costs (X2) (Dependent Variable)	The company's total budget allocation for maintenance activities, component replacement and repairs to the mechanical condition of the unit.	1. Adherence to the preventive maintenance schedule 2. Adequacy of the budget for spare parts and lubricants 3. Prompt corrective maintenance 4. Cost efficiency of technical services and overhauls	Likert scale (1-5)

Source: Authors' compilation

3.5. Data Collection Techniques

Data collection was carried out using three main techniques. The first was a questionnaire, a structured set of questions distributed directly to 62 respondents to obtain quantitative data on variables X1, X2, and Y. The second was a documentary study, involving the collection of secondary data through a review of historical cost records, maintenance reports, and summaries of the company's heavy machinery operational performance. The third was field observation, involving direct observation of the equipment mobilization process and routine maintenance procedures at the PT Sarana Baja Perkasa workshop to validate the questionnaire responses.

3.6. Data Analysis Techniques

Data processing in this study was carried out using SPSS software, beginning with instrument quality testing to ensure the questionnaire was suitable for use. The validity test was conducted using the Pearson product-moment correlation formula, where an item is considered valid if r-value > r-table at a 5% significance level (for N = 62, r-table = 0.250), while the reliability test used Cronbach's Alpha formula, with a variable considered reliable if its alpha value > 0.60. Before conducting multiple regression analysis, the model was also tested using classical assumption tests, including the normality test (Kolmogorov-Smirnov method, where residuals are considered normally distributed if the Asymp. Sig. (2-tailed) value is >0.05), the multicollinearity test (with criteria of a Tolerance value >0.10 and VIF <10.0), and the heteroscedasticity test using the Glejser test and scatterplot analysis, where the model is considered free from heteroscedasticity if the Glejser test's significance value is >0.05.

Once the classical assumptions were satisfied, multiple linear regression analysis was performed to determine the direction and magnitude of the effect of Mobility Costs (X1) and Maintenance Costs (X2) on Heavy Equipment Operations (Y). Hypothesis testing was carried out through the t-test (partial test) to examine the individual effect of each independent variable on the dependent variable, and the F-test (simultaneous test) to examine the combined effect of both independent variables on the dependent variable, with the decision criterion that the simultaneous hypothesis (H3) is accepted if F-calculated > F-table or the significance value is <0.05. In addition, the coefficient of determination (R^2) was analyzed to determine how much of the variation in the dependent variable could be explained by the independent variables in the regression model.

4. Results and Discussion

4.1. Research Results

4.1.1. Respondents Demographic

PT Sarana Baja Perkasa's Tangerang Branch is a business entity specializing in the supply and hire of heavy machinery to support construction, civil infrastructure and logistics projects. In carrying out its business activities, the smooth running of the fleet depends heavily on the accuracy of the equipment dispatch process and the effectiveness of the maintenance management program.

Primary data collection was carried out by distributing questionnaires to the entire target population of 62 respondents (N=62), comprising operational management, technical supervisors, senior mechanics, site supervisors and heavy machinery operators. A summary of the respondents' demographic characteristics is presented in Table 3.

Table 3. Demographic Profile of Respondents (N=62)

Category	Classification	Number (of people)	Percentage (%)
Gender	Men	32	51.61%
	Women	30	48.39%
Age Group	20-30 years old	36	58.06%
	31-40 years old	18	29.03%
	> 40 years old	8	12.91%
Level of Education	Bachelor's degree (S1)	53	85.48%
	Diploma (D3) / Upper Secondary School (SMA) / Equivalent	9	14.52%
Length of Service	< 2 years	12	19.35%
	2-5 years	38	61.29%
	> 5 years	12	19.35%

Source: Data processed

Based on Table 3, the respondent profile was dominated by workers of working age (20-30 years, accounting for 58.06 per cent), the majority of whom held a Bachelor's degree (85.48 per cent) and had worked for 2-5 years (61.29 per cent). This profile indicates that the respondents possess the intellectual capacity, technical understanding and sufficient practical experience to provide objective and accurate assessments regarding the variables of mobility, maintenance and the operation of heavy machinery.

4.1.2. Description of Research Variables

Descriptive statistics provide an overview of the distribution of the company's historical operational data and cost allocations over the observation period. A summary of the minimum, maximum, mean and standard deviation is presented in Table 4.

Table 4. Descriptive Statistics for the Research Variables

Variables	N	Minimum Value	Maximum Value	Mean	Standard Deviations
Mobility Costs (X1)	62	Rp5.000.000	Rp35.000.000	Rp18.250.000	Rp6.400.000
Maintenance Costs (X2)	62	Rp3.000.000	Rp50.000.000	Rp22.100.000	Rp9.200.000
Heavy Equipment Operations (Y)	62	Rp15.000.000	Rp85.000.000	Rp45.000.000	Rp15.500.000

Source: Data processed

Based on Table 4, Mobility Costs (X1) average Rp18,250,000 per transport event, ranging from Rp5,000,000 to Rp35,000,000 depending on the distance to the project site, terrain accessibility, and the type of transport fleet (lowbed/towing) used. Maintenance Costs (X2) average Rp22,100,000, with a standard deviation of Rp9,200,000 and a maximum of Rp50,000,000 during periods of major overhauls and critical engine component replacement. Heavy Equipment Operations (Y) average Rp45,000,000, adjusted according to the Hour Meter performance index and equipment availability rate.

4.1.3. Results of the Instrument Quality Test and Classical Assumptions

A. Validity and Reliability Testing of Instruments

Before the data were analyzed further, validity and reliability tests were carried out on the questionnaire items. The validity test used Pearson's product-moment correlation, and the results show that all statement items for variables X1, X2, and Y have calculated r values ranging from 0.657 to 0.900, which are greater than the table r value of 0.250 (at N=62, $\alpha=0.05$), meaning all items in the instrument are deemed valid. The reliability test was based on Cronbach's Alpha, and the results yielded a Cronbach's Alpha value above 0.80 for all three variables, above the threshold of 0.60, demonstrating that the research instrument possesses very high reliability and internal consistency.

B. Data Normality Test

The normality test aims to determine whether the residuals in the regression model are normally distributed. The test utilizes the one-sample Kolmogorov-Smirnov test.

Table 5. Results of the Kolmogorov-Smirnov Normality Test

Statistical Indicators	Unstandardized Residual
N	62
Test Statistic	0.078
Asymp. Sig. (2-tailed)	0.200

Source: Data processed

Based on Table 5, the value of Asymp. Sig. (2-tailed) is 0.200 > 0.05. This confirms that the residual data are normally distributed, and therefore the assumption of normality is satisfied.

C. Multicollinearity Test

A multicollinearity test was carried out to ensure that there was no perfect or very strong correlation between the independent variables in the regression model.

Table 6. Results of the Multicollinearity Test

Independent Variables	Tolerance	VIF	Note
Mobility Costs (X1)	0.712	1.404	Free from multicollinearity
Maintenance Costs (X2)	0.712	1.404	Free from multicollinearity

Source: Data processed

The results of the multicollinearity test in Table 6 show a Tolerance value of 0.712 (>0.10) and a Variance Inflation Factor ('VIF') value of 1.404 (<10.0). It can therefore be concluded that the regression model is free from multicollinearity.

D. Heteroscedasticity Test

The heteroscedasticity test uses the Glejser test, which involves dividing the absolute values of the residuals ("Abs_RES") by the independent variables.

Table 7. Results of the Heteroscedasticity Test (Glejser Test)

Independent Variables	Parameter Coefficient	t-statistic	Sig.	Description
Mobility Costs (X1)	-0.082	-0.826	0.412	No Heteroscedasticity
Maintenance Costs (X2)	0.094	1.078	0.285	No Heteroscedasticity

Source: Data processed

Based on Table 7, the significance values for variables X1 (p = 0.412) and X2 (p = 0.285) are above 0.05. This is further evidenced by the distribution of data points on the scatterplot, which are randomly scattered above and below the value of 0 on the Y-axis; consequently, the regression model is deemed free from heteroscedasticity.

4.1.4. Results of Multiple Linear Regression Analysis and Hypothesis Testing

The analysis of multiple linear regression data yielded regression coefficients, the t-statistic, the F-statistic and the coefficient of determination, which are summarized in Table 8.

Table 8. Results of Multiple Linear Regression Analysis, t-test, F-test and R^2

	Model / Variables	Unstandardized Coefficients		Standardized Coefficients	t-value	Sig.
		β	Std. Error	Beta		
1	(Constant)	8.412	2.105	-	3.996	0.000
	Mobility Costs (X1)	0.342	0.092	0.331	3.717	0.000
	Maintenance Costs (X2)	0.518	0.085	0.542	6.094	0.000
	Model Evaluation	R=0.789	R^2=0.622	Adjusted R^2=0.609	F-Value =48.612	Sig. F=0.000

Source: Data processed

A. Multiple Linear Regression Equation

Based on the β coefficients in Table 8, the mathematical formulation of multiple linear regression is:

$$Y = 8.412 + 0.342X_1 + 0.518X_2 + e$$

The regression equation is interpreted as follows: the constant (α=8.412) indicates that if the Mobility Cost (X1) and Maintenance Cost (X2) variables are zero, the baseline value for Heavy Equipment Operations (Y) is 8.412 units. The regression coefficient for Mobility Costs (β_1=0.342) is a positive value, indicating a direct relationship, meaning every 1-unit increase in the effective allocation of mobility costs will increase heavy equipment operations by 0.342 units, assuming the maintenance cost variable remains constant. The regression coefficient for Maintenance Costs (β_2=0.518) is also a positive value, indicating a direct relationship, meaning every 1-unit increase in the allocation of maintenance costs will increase heavy equipment operational output by 0.518 units, assuming the mobility cost variable remains constant.

B. Partial Hypothesis Testing (t-test)

The t-test was used to test the significance of the effect of each independent variable on the dependent variable (df = N – k – 1 = 62 – 2 – 1 = 59; t table = 2.001). For Hypothesis Testing 1 (H1), the Mobility Cost variable (X1) yielded a calculated t-value of 3.717, greater than the table t-value of 2.001, with a significance level of p=0.000 < 0.05, a result that rejects Ho and accepts H1, meaning that Mobility Costs have a positive and statistically significant partial effect on Heavy Equipment Operations. For Hypothesis Testing 2 (H2), the Maintenance Costs variable (X2) yielded a calculated t-value of 6.094, also greater than the table t-value of 2.001, with a significance level of p=0.000 < 0.05, a result that rejects Ho and accepts H2, proving that Maintenance Costs have a positive and statistically significant partial effect on Heavy Equipment Operations.

C. Simultaneous Hypothesis Testing (F-Test)

An F-test was carried out to examine the combined effect of the two independent variables on the dependent variable ($df_1 = 2, df_2 = 59; F_{\text{table}} = 3{,}153$). The calculated F-value obtained is 48.612 > the table F-value of 3.153, with a significance level of p = 0.000 < 0.05. Therefore, H_0 is rejected and H_3 is accepted, confirming that Mobility Costs and Maintenance Costs simultaneously have a significant effect on the operation of heavy machinery at PT Sarana Baja Perkasa.

D. Analysis of the Coefficient of Determination (R^2)

Based on Table 8, the Coefficient of Determination (R^2) was found to be 0.622, with an Adjusted R^2 of 0.609. This R^2 value indicates that 62.2 percent of the variability in Heavy Equipment Operational Performance can be explained by the combination of the Mobility Cost (X1) and Maintenance Cost (X2) variables, while the remaining 37.8 percent (100 percent – 62.2 percent) is explained by other variables outside the scope of this study, such as operator competence levels, geological and weather conditions at the project site, and the age of the heavy equipment units.

4.2. Discussion

4.2.1. The Impact of Mobility Costs on Heavy Machinery Operations

Empirical test results demonstrate that mobility costs have a positive and significant effect on the operation of heavy machinery ($\beta_1 = 0.342$; $p < 0.05$). This finding confirms that the allocation of an adequate mobility budget should not be viewed merely as an expense (cost center), but rather as a strategic logistical investment that ensures the smooth running of the project's supply chain.

The planned allocation of mobility costs enables the use of a specialized transport fleet (low-bed trailers in prime condition), the selection of the safest routes, and the securing of road permits and official escorts. This directly minimizes travel downtime (delays in arriving at the project site) and prevents potential damage to mechanical structures caused by extreme vibrations during transport. Units arriving on time and in safe condition can be put into operation immediately (zero idle time), thereby boosting the units' hour-meter utilization on site. These research findings reinforce the conclusions of Turbaningsih (2022) and Liu et al. (2024), who state that the efficiency of logistics for high-cost cargo shipments is directly proportional to work effectiveness at the destination site.

4.2.2. The Effect of Maintenance Costs on Heavy Equipment Operations

Maintenance costs have been shown to have the most significant impact on heavy equipment operations, as indicated by the regression coefficient ($\beta_2 = 0.518$) and the calculated t-value = 6.094. This finding confirms that the physical and mechanical reliability of heavy equipment is a key pillar in achieving the rental industry's operational targets.

Adequate maintenance budget allocation facilitates the implementation of Reliability-Centred Maintenance (RCM) and regular preventive maintenance, such as the timely replacement of engine oil, hydraulic fluid, undercarriage repairs and filter changes. This planned maintenance approach significantly reduces the incidence of breakdowns whilst the equipment is operating under heavy workloads. From the perspective of Asset Life Cycle Theory, investment in the maintenance phase effectively maintains Mechanical Availability (MA) above the ideal operational standard (>85 per cent), minimizes losses due to unscheduled downtime, and extends the economic life of the unit (Febrianto et al., 2025; Purnomo, 2025; Deng et al., 2025).

4.2.3. Simultaneous Effects and Operational Synergy

Simultaneous testing ($F=48.612$; $p<0.05$) demonstrated a very strong synergistic relationship between mobility logistics efficiency (upstream chain) and technical maintenance reliability (downstream chain). The combined contribution of 62.2 per cent indicates that the operational management of heavy machinery cannot be managed in isolation.

Synergy Implications: Heavy machinery that is meticulously maintained in the workshop (X_2) will not yield economic benefits for the company if it experiences delivery delays or breakdowns during the mobilization process (X_1). Conversely, a swift and timely mobilization process (X_1) will be rendered futile if the unit suffers an engine breakdown at the project site due to negligence in routine maintenance (X_2).

These findings support the framework for the integration of operational management accounting proposed by Wattimena and Witjaksana (2023), in which the efficiency of delivery logistics costs and the assurance of machinery's technical readiness are the two main pillars for maximizing unit productivity and maintaining an efficient Total Cost of Ownership (TCO).

4.2.4. Practical and Managerial Implications for Companies

Based on the research findings, some strategic recommendations that could be implemented by the management of PT Sarana Baja Perkasa include the following. The first is digitization of maintenance management, transitioning from a manual record-keeping system to a Computerized Maintenance Management System (CMMS) to monitor machine operating hours (hour meter) in real time, so that preventive maintenance schedules and spare part replacements can be carried out on time. The second is standardization of mobility costs based on zoning, drawing up Standard Operating Procedures (SOPs) for setting mobility budgets based on distance zoning and the level of terrain difficulty at project sites, which is essential to prevent uncontrolled fluctuations in logistics costs. The third is enhanced pre-mobilization training and inspections, mandating comprehensive technical inspections (pre-dispatch inspections) before units are loaded onto low-bed trailers to ensure equipment is 100 percent operational upon arrival at the client's site.

5. Conclusion

Based on the results of the data analysis and empirical discussion carried out, this study has drawn three main conclusions. Firstly, mobility costs have been shown to have a positive and statistically significant partial effect on the operation of heavy machinery at PT Sarana Baja Perkasa. A well-planned allocation of the logistics budget, including the provision of a dedicated transport fleet, sufficient fuel for journeys, and the fulfillment of administrative requirements for permits and route escorts, effectively minimizes travel downtime and ensures that units arrive at the project site in a ready-to-operate condition.

Secondly, maintenance costs were found to have a positive and statistically significant partial effect on the operation of heavy equipment, while also being the most dominant variable in determining the company's operational performance. Adequate budgetary support for the implementation of routine preventive maintenance, the timely replacement of spare parts, and periodic repairs proved effective in minimizing unscheduled downtime and maintaining the units' Mechanical Availability (MA) at an optimum level.

Thirdly, mobility costs and maintenance costs simultaneously have a significant impact on the operation of heavy machinery at PT Sarana Baja Perkasa, contributing 62.2 percent to the overall impact. The synergy between the efficiency of logistics chain management at the upstream stage and the reliability of technical maintenance of machinery at the downstream stage forms the operational resilience that underpins the achievement of the units' daily productivity in the field.

The results of this study have significant theoretical implications for the development of operations management and management accounting. These empirical findings reinforce and extend the Asset Life Cycle Theory within the high-cost capital-intensive asset rental industry. This study conceptually demonstrates that the management of productive assets requires an integrated model combining spatial logistics cost control (mobility) and reliability-centered maintenance (RCM), whereby efficiency in both these cycles determines the level of sustainability of the assets' economic function.

From a practical and managerial perspective, the findings translate into the strategic recommendations outlined in the Discussion, centered on digitalizing maintenance management and standardizing mobility cost planning by project zoning, both of which are intended to strengthen PT Sarana Baja Perkasa's operational resilience while keeping its rental pricing competitive.

This study has several limitations that need to be taken into account for the improvement of future research. The main limitation lies in the scope of the independent variables, which focus solely on mobility costs and maintenance costs, as well as the limited scope of the research subject, which is restricted to a single company, namely PT Sarana Baja Perkasa's Tangerang Branch, with a sample size of 62 respondents. This means that operational dynamics influenced by external factors have not been fully captured in this regression model.

In light of these limitations, future researchers are advised to expand the conceptual framework by integrating additional relevant independent variables, such as the competence and experience of operators, the machine working hour utilization ratio (Hour Meter), and the age of the heavy equipment. Furthermore, future research is also recommended to broaden the scope of the population and sample across multiple regions by involving several heavy machinery rental service providers in order to enhance the generalizability and comparative validity of the research findings.

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