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RESEARCH ARTICLE

THE EFFECT OF PROJECT MATERIALS ON TIME PERFORMANCE IN THE IMPLEMENTATION OF ROAD WORKS IN BIAK NUMFOR REGENCY

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Abstract

Road construction projects in Biak Numfor Regency face challenges related to material availability, high logistics costs, limited transportatio n access, and the geographical characteristics of an archipelagic region, all of which affect project time performance. This study aims to analyze the effect of material factors on project time performance, identify the supporting and inhibiting factors, and formulate strategies to improve project time performance. A quantitative research approach was employed using a survey method involving 50 respondents representing project owners, consultants, and contractors. The data were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The results indicate that material factors have a positive and significant effect on project time performance (path coefficient = 0.755, T-statistic = 12.970, P-value = 0.000), with an R-square value of 0.594. Material quality was identified as the primary supporting factor, whereas the availability of material quantities was the main inhibiting factor. The recommended strategies include improving material quality, optimizing material planning, strengthening procurement and distribution systems, and enhancing material storage supervision.

Introduction:-

Road infrastructure development is one of the main factors in improving regional connectivity, economic growth, and equitable development. The success of a road construction project is generally measured based on the achievement of cost, quality, and implementation time. Among the various resources used in construction projects, materials have the greatest contribution to project costs as well as being a factor that greatly determines the productivity of work in the field. Therefore, effective material management, starting from needs planning, procurement, supplier selection, storage, to material distribution, is one of the important aspects in maintaining the smooth implementation of the project. Studies have shown that inaccurate material management can lead to delays in work, increased construction costs, and decreased project performance(Al-Aidrous et al., 2022; Pham Van & Peansupap, 2024; Rens, 2016; Yıldız et al., 2024; Z. Zhou et al., 2021). In fact, recent research confirms that an

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efficient material supply chain system can increase productivity while reducing cost wastage in road construction projects(Borah et al., 2025).

Although the concept of material management has developed well, its application still faces various challenges in regions with special geographical characteristics. Biak Numfor Regency as an archipelago in Papua Province has different geographical conditions from the main mainland area in Indonesia. The distribution of islands, limited transportation networks, and dependence on sea and air transportation have caused the distribution of construction materials to be more complex. On the other hand, road infrastructure development is still a priority for local governments to improve connectivity between regions. However, limited access to the job site often increases the cost of transporting materials, extending delivery times, and even in certain conditions requires special modes of transportation such as helicopters. This condition has an impact on increasing project implementation costs and has the potential to hinder the equitable distribution of road infrastructure development in Biak Numfor Regency.

Various studies have identified that material availability, procurement systems, supplier reliability, transportation, storage, and inventory control are factors that affect the success of construction projects. Studies on construction supply chain management also show that good coordination between project owners, contractors, suppliers, and related parties can improve the efficiency of material distribution and reduce the risk of project delays. In addition, a number of international studies have developed various material supply chain management models that aim to optimize the process of procurement and distribution of materials in road projects so that project productivity can be increased.

Nonetheless, most previous research has still focused on aspects of supply chain coordination, procurement efficiency, and the relationship between suppliers and contractors. The study has not studied much how the characteristics of local material availability in the archipelago area affect the time performance of road construction projects. (Hardina, 2022) For example, it was found that dependence on materials from outside the region, limited delivery schedules, and weather conditions and sea waves had a significant influence on the performance of construction projects in the archipelago. The research shows that the material supply chain contributes around 70% to project performance. However, the study focuses more on the material distribution aspect and has not specifically identified the material factors that most affect the project's time performance and handling strategies based on local conditions.

Based on the results of previous studies, there is still a research gap regarding the influence of material factors on the performance of road project implementation time in the archipelago area which has limited accessibility and high logistics costs. Most studies examine material management from a general supply chain perspective, while studies that comprehensively evaluate various aspects of materials—such as material availability, price, mobilization, quality, storage, supplier availability, material breakdown, procurement accuracy, material location access, and inventory control—on the timing performance of road projects in the archipelago. Therefore, research is needed that is able to explain the material factors that have the most influence on the project implementation time as well as provide recommendations for strategies to overcome them.

The novelty of this research lies in an analysis that integrates various dimensions of material management in one model to evaluate its influence on the performance of road project implementation time in Biak Numfor Regency. In contrast to previous research that focused more on the supply chain aspect in general, this study not only identifies the influence of material factors on project time performance, but also determines the main inhibiting factors and formulates a handling strategy that is in accordance with the characteristics of the archipelago. Thus, this research is expected to enrich the study of material management in infrastructure projects in remote areas while providing a more effective decision-making basis for stakeholders.

Based on this description, this study aims to analyze the influence of materials on time performance in the implementation of road works in Biak Numfor Regency, identify the inhibiting factors that affect the relationship, and formulate strategies that can be applied to overcome obstacles so that the implementation of the project can take place more effectively and on time.

The results of this research are expected to contribute academically and practically. Academically, this research can enrich the development of science in the field of construction management, especially related to material management in road projects in the archipelago. Practically, the results of the research are expected to be input for local governments, planning consultants, contractors, and other stakeholders in developing more efficient material

management strategies, improving the timeliness of project implementation, reducing logistics costs, and supporting the development of more equitable and sustainable road infrastructure in Biak Numfor Regency.

Theory:-

Construction Project Management Theory:-

Construction project management is the process of planning, organizing, implementing, and controlling all project resources to achieve cost, quality, and time goals effectively. The success of the project is not only influenced by the technical capabilities of the implementation, but also by the effectiveness of resource management, especially materials, labor, equipment, work methods, and financing. In road projects, materials are one of the most dominant resources because they contribute the largest proportion of costs and determine the smooth running of each stage of work. Therefore, good material management is one of the main factors in achieving the target project completion time(Willar et al., 2023; H. Zhou et al., 2024).

Material Management Theory:-

Material management is a material management process from the planning of needs, procurement, purchasing, delivery, storage, use, to inventory control during the implementation of construction projects. The main goal of material management is to ensure that materials are available in sufficient quantities, quality to specifications, the right location, the right time, and cost efficient. Effective material management reduces waste, prevents work delays, increases productivity, and supports the successful completion of construction projects(Awaad et al., 2024; Caldas et al., 2014).

Material Availability Theory:-

Material availability is a condition for meeting the material needs of the project in accordance with the number, quality, time, location, and cost that has been planned. In road work, materials such as aggregates, crushed stone, sand, cement, asphalt, and landfill must be available on an ongoing basis so that each stage of construction can run on schedule. Delays or shortages of materials can lead to disruption of construction activities, decrease productivity, and extend project completion time. In archipelagic areas such as Biak Numfor Regency, the availability of materials is influenced by geographical conditions, transportation access, supplier capacity, weather, and the distance of the material source to the project site(Kedir & Hall, 2021; Yu et al., 2021)

Theory Material Local:-

Local materials are construction materials that are available around the project site and have the potential to be used as road work materials if they meet technical requirements. The use of local materials can reduce dependence on materials from outside the region, reduce transportation costs, speed up procurement time, and increase the efficiency of project implementation. However, local materials must meet the required quality standards, such as strength, gradation, cleanliness, and carrying capacity before being used in road construction. Therefore, the identification of local material potential is one of the important efforts in increasing the effectiveness of infrastructure development, especially in remote areas and islands(Daku et al., 2024; Foko Tamba et al., 2023; Murty & Krishna, 2023)

Project Time Performance Theory:-

Project time performance is the level of success of project implementation in completing all work according to the planned schedule. Time performance is influenced by various factors, such as project planning, resource management, coordination between parties, and smooth supply of materials. The more effective the material management, the less risk of delays in work so that the project completion target can be achieved as planned. On the other hand, disruptions in the procurement, distribution, and material control processes can cause schedule deviations and reduce project time performance. Thus, time performance is an important indicator in assessing the success of the implementation of road construction projects.

Method:-

This study uses a quantitative method with a survey approach to analyze the influence of material factors on time performance in the implementation of road works in Biak Numfor Regency. This approach was chosen because it is able to measure the relationship between variables objectively through 1394epresent analysis based on Structural Equation Modeling (SEM-PLS). The research was carried out on a road work project in Biak Numfor Regency, Papua Province. This location was chosen because it has the characteristics of an archipelago that faces challenges in the procurement, distribution, and management of construction materials. Data collection will be carried out in 2026.

The research population includes all parties involved in the implementation of road projects in Biak Numfor Regency, namely the PUPR Office, implementing contractors, planning consultants, supervisory consultants, material suppliers, material transportation service providers, local governments, and technical personnel in the field. The sample was determined using the purposive sampling technique, namely respondents who had experience and direct involvement in the material management of road projects. The number of samples used was 55 respondents, in accordance with the minimum criteria for SEM-PLS analysis for research models that have several latent constructs. The research data consists of primary data and secondary data. Primary data was obtained through field observation, questionnaire distribution, and interviews with respondents who were directly involved in the implementation of road projects. Meanwhile, secondary data was obtained through project documents, 1395government epresent data, regulations, and various scientific literature relevant to the research.

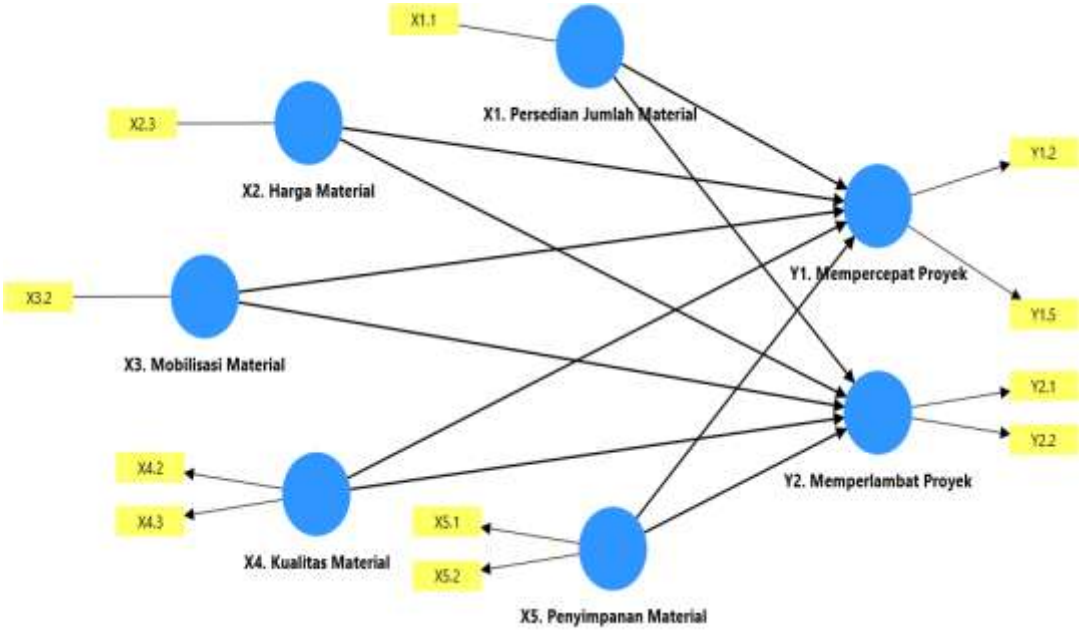
The research instruments were compiled based on indicators adapted from previous research on construction material management. The research variables include material availability, material price, material distribution or mobilization, material quality, material storage, procurement accuracy, supplier availability, material damage, material accessibility, inventory control, and project time performance. All indicators were measured using a five-point Likert scale, namely 1 = strongly disagree to 5 = strongly agree.

Data analysis was carried out using SmartPLS software with the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach. This method was chosen because it is able to analyze the relationship between latent variables simultaneously, is suitable for research models that have many indicators, do not require normal data distribution, and can be used on relatively limited sample sizes.

The analysis stages include the evaluation of the measurement model (outer model) and structural model (inner model). The evaluation of the outer model was carried out through convergent validity tests (outer loading and Average Variance Extracted/AVE), discriminant validity (cross loading and Fornell–Larcker Criterion), and reliability tests using Composite Reliability and Cronbach's Alpha. Furthermore, the internal model evaluation was carried out through testing the value of the determination coefficient (R^2), predictive relevance (Q^2), effect size (f^2), and hypothesis testing using a bootstrapping procedure based on t-statistics and p-values at a significance level of 5%.

Result and Discussion:-

This study involved 55 respondents consisting of contractors (26%), consultants (22%), service owners (16%), site engineers (16%), foremen (10%), supervisors (6%), and 1395material press personnel (4%). By age, the majority of respondents were over 45 years old (34%) and 36–45 years old (32%). In terms of work experience, as many as 60% of respondents have 6–10 years of experience, while 34% have worked for more than 10 years. In addition, 1395 a large proportion of respondents had a bachelor's (84%) and postgraduate (10%) education. These characteristics show that the research data was obtained from respondents who have sufficient experience and competence in the implementation of road projects so that they are able to provide 1395an epresentative assessment of material factors that affect project time performance.



Based on the model, this study analyzed the influence of five exogenous (X) variables related to materials against two endogenous variables (Y) related to project time performance. The exogenous variables consist of X1 Inventory Quantity of Materials, X2 Material Price, X3 Material Mobilization, X4 Material Quality, and X5 Material Storage, while the endogenous variables consist of Y1 Accelerating the Project and Y2 Slowing the Project. Each latent variable is measured by several indicators, where X1 is represented by the X1.1 indicator, X2 by the X2.3 indicator, X3 by the X3.2 indicator, X4 by the X4.2 and X4.3 indicators, X5 by the X5.1 and X5.2 indicators, Y1 by the Y1.2 and Y1.5 indicators, and Y2 by the Y2.1 and Y2.2 indicators.

Tabel 1 R Square

	R-square	R-square adjusted
Y1. Accelerating Projects	0.594	0.553
Y2. Slowing down the project	0.197	0.115

Source: Data Analytics, 2026

Based on the results of the R-Square analysis, the variable Accelerating the Project (Y1) has an R^2 value of 0.594, which shows that 59.4% of the variation in project acceleration can be explained by the variables of inventory of the amount of material, material price, material mobilization, material quality, and material storage, while the remaining 40.6% is influenced by other factors outside the model. This value is included in the moderate category, so the model has a fairly good ability to explain the acceleration of the project. Meanwhile, the variable Slowing down the Project (Y2) had an R^2 value of 0.197, which means that material factors were only able to explain 19.7% of the variation in project delays, while 80.3% were influenced by other factors that were not analyzed. Overall, these results show that the research model is better able to explain the factors that support the acceleration of the project than the factors that cause the delay of the project.

Tabel 2 F Square

	f-square
X1. Material Quantity Inventory -> Y1. Accelerating Projects	0.004
X1. Inventory Quantity of Materials -> Y2. Slowing down the project	0.014
X2. Material Price -> Y1. Accelerating Projects	0.012

X2. Material Price -> Y2. Slowing down the project	0.003
X3. Material Mobilization -> Y1. Accelerating Projects	0.031
X3. Material Mobilization -> Y2. Slowing down the project	0.001
X4. Material Quality -> Y1. Accelerating Projects	0.161
X4. Material Quality -> Y2. Slowing down the project	0.006
X5. Material Storage -> Y1. Accelerating Projects	0.019
X5. Material Storage -> Y2. Slowing down the project	0.007

Source: Data Analytics, 2026

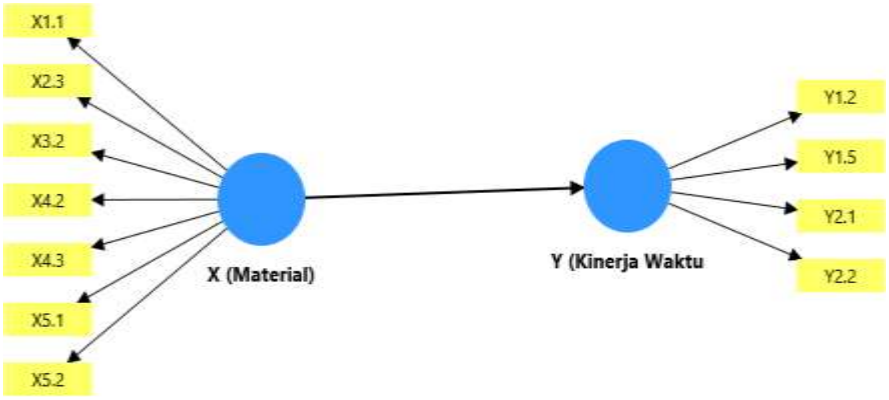
Based on the results of the effect size (f^2) analysis, Material Quality (X4) is the variable that has the greatest influence on Accelerating the Project (Y1) with a value of $f^2 = 0.161$, which is included in the category of medium effect. Meanwhile, Material Mobilization (X3) showed a small influence ($f^2 = 0.031$), while Material Quantity Inventory (X1), Material Price (X2), and Material Storage (X5) had a very small influence ($f^2 < 0.02$). In the Project Slowing variable (Y2), all material variables had a value of f^2 below 0.02, which indicates a very small contribution to project delays. Overall, these results show that Material Quality is the most dominant material factor in improving project time performance, while other material variables contribute relatively low.

Table 3 Path Coefficients

X1. Material Quantity Inventory -> Y1. Accelerating Projects	0.070	0.124	0.219	0.319	0.750
X1. Inventory Quantity of Materials -> Y2. Slowing down the project	0.176	0.191	0.205	0.855	0.393
X2. Material Price -> Y1. Accelerating Projects	0.104	0.098	0.136	0.763	0.446
X2. Material Price -> Y2. Slowing down the project	0.073	0.091	0.223	0.329	0.742
X3. Material Mobilization -> Y1. Accelerating Projects	0.168	0.158	0.162	1.036	0.300
X3. Material Mobilization -> Y2. Slowing down the project	0.032	0.043	0.178	0.177	0.860
X4. Material Quality -> Y1. Accelerating Projects	0.411	0.366	0.192	2.145	0.032
X4. Material Quality -> Y2. Slowing down the project	0.113	0.120	0.193	0.584	0.559
X5. Material Storage -> Y1. Accelerating Projects	0.143	0.138	0.166	0.865	0.387
X5. Material Storage -> Y2. Slowing down the project	0.123	0.117	0.162	0.754	0.451

Source: Data Analytics, 2026

Based on the results of the path coefficients test, only Material Quality (X4) had a positive and significant effect on Accelerating the Project (Y1) with a path coefficient of 0.411, a t-statistics value = 2.145, and a p-value = 0.032. These results show that the better the quality of the materials used, the greater the chance of the project being completed on time. Meanwhile, the variables Inventory of Quantity of Materials (X1), Material Price (X2), Material Mobilization (X3), and Material Storage (X5) did not show a significant influence on the acceleration of the project because they had a p-value of > 0.05. In addition, all material variables also did not have a significant effect on Project Slowing (Y2). Thus, the results of the study indicate that material quality is the main factor that contributes to improving the time performance of road projects in Biak Numfor Regency, while other material factors have not shown a significant influence. "The test results showed that of the five material factors analyzed, only material quality had a significant effect on project time performance ($\beta = 0.411$; $t = 2.145$; $p = 0.032$), while other material factors showed no significant influence ($p > 0.05$)."



The image shows the SEM-PLS research model that tests the effect of Material (X) on Time Performance (Y) on construction projects. The Material Variable (X) is an exogenous latent variable formed by seven indicators, namely X1.1, X2.3, X3.2, X4.2, X4.3, X5.1, and X5.2. These indicators represent material aspects that are considered to be able to describe material management conditions in the implementation of the project. The arrow direction of the Material construct towards the indicator indicates that the indicators are used to measure the latent variable of the Material.

Meanwhile, the Time Performance variable (Y) is an endogenous latent variable measured by four indicators, namely Y1.2, Y1.5, Y2.1, and Y2.2. The Y1 indicator represents the aspects related to the acceleration of the project, while the Y2 indicator represents the aspects related to the project delay. The four indicators are used together to explain the on-time performance level of a construction project.

The Influence of Materials on Time Performance in the Implementation of Road Works in Biak Numfor Regency

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
X (Material) -> Y (Time Performance	**0.755**	**0.777**	**0.058**	**12.970**	**0.000**

The results of the SEM-PLS analysis showed that materials had a positive and significant effect on project time performance with a path coefficient of 0.755 ($t = 12.970$; $p < 0.001$). These findings show that the better the material management, including aspects of availability, price, mobilization, quality, and storage, the higher the project's ability to achieve the planned time target. These results confirm that materials are one of the main resources that determine the smooth implementation of road works, especially in areas with limited access such as Biak Numfor Regency.

These findings are in line with the research of Tanubrata and Gunawan (2018), Wayrah et al. (2021), and Awaad et al. (2024) which stated that effective material management can increase productivity and reduce construction project delays. Thus, improving the material management system, from needs planning to control in the field, is an important aspect in supporting the timely completion of road projects.

Inhibiting and Supporting Factors of Material Influence on Time Performance:-

The results show that Material Quality is the most dominant supporting factor in improving project time performance, while Material Quantity Inventory is the most potentially inhibiting project completion. Materials that meet technical specifications can reduce rework and increase productivity, while limited material quantities can hinder work progress, making time targets difficult to achieve. These results support the research of Al-Aidrous et al. (2022) and Munkombwe and Chibomba (2025) which emphasize the importance of quality and availability of materials in the success of construction projects. Therefore, material quality control and accurate planning of material needs need to be a priority to minimize the risk of delays in road projects in Biak Numfor Regency.

Strategies to Overcome Factors Inhibiting the Influence of Materials on Time Performance:-

The main recommended strategy is to strengthen the material management system through material requirement planning, provision of safety stock, material quality control, improved distribution coordination, and improvement of the storage system at the project site. The strategy is directed to overcome material availability constraints while maintaining material quality as the most influential factor on project time performance. The implementation of the strategy is expected to be able to reduce the risk of distribution delays, material damage, and rework, so that the productivity of project implementation can increase. Given the geographical condition of Biak Numfor Regency as an archipelago, the success of material management also requires good coordination between the government, contractors, suppliers, and transportation service providers so that materials are available in the right quantity, quality, and on time

Conclusion:-

1. Road project materials have a positive and significant effect on the performance of road work implementation time in Biak Numfor Regency. The results of the analysis showed that the path coefficient value was 0.755, the T-statistical value was 12.970, and the P-value was 0.000, which indicates that the better the material management, the better the project time performance. Thus, road project materials are one of the important factors that determine the success of achieving the target time for the implementation of road projects.
2. The main inhibiting factor in the influence of materials on time performance is problems with the inventory or availability of the amount of materials. The results of the analysis show that the Material Quantity Inventory variable has the largest Total Effect value on project delays of 0.176, so it is the factor that has the most potential to hinder the achievement of the target time for the implementation of road works. In addition, delays in material mobilization, fluctuations in material prices, material quality that is not in accordance with specifications, and poor material storage systems also have the potential to hamper project time performance, although the effect is not partially significant.
3. Strategies that can be carried out to increase the influence of materials on project time performance are to strengthen the management of material inventory through accurate needs planning, maintain material quality according to technical specifications, optimize the material mobilization and distribution system, improve material storage management, and strengthen coordination and supervision in the material procurement process. The implementation of this strategy is expected to minimize the risk of delays and support the acceleration of the completion of road works in Biak Numfor Regency according to the set schedule.

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