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Evaluation of the COVID-19 Pandemic's Impact on Cost, Quality, and Time in Road Infrastructure Development in East Lombok Regency in 2021: Regression Approach and Fault Tree Analysis (FTA)

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ABSTRACT: *The onset of the COVID-19 pandemic in late 2019 has substantially influenced multiple industries, notably the sector responsible for constructing road infrastructure. This study aims to assess the effects of the COVID-19 pandemic on the expenses, standards, and duration of road infrastructure development in East Lombok Regency in 2021. This will be accomplished by employing a regression methodology and Fault Tree Analysis (FTA). This study utilizes data from 13 road-building projects conducted in East Lombok Regency in 2021 as the population, and 7 projects are selected as samples using the Purposive Sampling technique. A regression study was conducted to examine the correlation between independent variables associated with the pandemic (such as the extent of lockdown measures, the rate of COVID-19 spread, and government policies) and dependent variables (including cost, quality, and construction time). The regression analysis conducted in the simultaneous test (F Test) indicates that the Lockdown Level, the Level of Spread of COVID-19, and Government Policy collectively do not significantly impact the Cost and Quality of Road Infrastructure Development. This conclusion is based on the calculated F value being less than the F table value, with a significance level greater than 0.05. Nevertheless, these three variables exert a substantial impact on the Road Infrastructure Development Time variable, as evidenced by the estimated F value being greater than the F table value and the significance threshold being less than 0.05. FTA analysis is employed to identify risk factors in the variable of development time, specifically those that exert a substantial influence according to the outcomes of the regression analysis. The FTA analysis, using top-even reduction as a representative construction time variable, revealed four main risk factors that negatively affected project implementation effectiveness. These factors include a high probability (0.84) of disruption in the material supply chain, a medium probability (0.56) of decreased availability and productivity of labor, a high probability (0.72) of disruption in coordination and communication between project teams, and a very high probability (0.97) of increased occupational health and safety risks. The likelihood of a deterioration in the effectiveness of project implementation is 0.99, which falls into the very high category. This means that the event is almost definitely to occur. Based on the findings of this study, many measures are suggested to alleviate the effects of the pandemic. These measures include expanding the range of supply sources, enhancing worker awareness and training, utilizing communication technologies for virtual meetings, and implementing rigorous health protocols. The use of these techniques is expected to enhance the sustainability and efficacy of road infrastructure development projects in East Lombok Regency, both during the pandemic and in the future.*

Keywords: *COVID-19, infrastructure development, regression, Fault Tree Analysis (FTA), risk management.*

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I. INTRODUCTION

The COVID-19 pandemic has caused significant disruption in various sectors, including road infrastructure construction in East Lombok Regency. Strict social distancing policies and health protocols impact project implementation, increase costs and pose management challenges. The construction sector, one of the key pillars of economic development, has strongly felt the impact of this pandemic. Project delays, increased costs, and decreased quality of work are some challenges due to this pandemic.

According to the World Health Organization [1], this pandemic has caused major disruption to health, economic, and social systems throughout the world. Various sectors, including construction, have had to face the challenge of maintaining operations while ensuring worker safety and adhering to strict health protocols.

The COVID-19 pandemic has impacted not only the availability of labor and materials, but also the way people work and interact at the project site [2]. Social restrictions and health protocols, such as maintaining

distance and wearing masks, have changed the dynamics of work in the field [3]. Additionally, disruptions in global supply chains cause delays in the delivery of materials and equipment, which have a direct impact on project time and costs. Previously, stakeholders may not have prioritized the use of digital technology for communication and project coordination, but the pandemic has forced them to adapt.

The Impact of the COVID-19 Pandemic on the Construction Sector

The construction sector is one of the sectors most affected by the COVID-19 pandemic. According to Parinduri and Parinduri [4], the pandemic's impact on the construction sector manifests in several key areas:

1. Worker Health and Safety: Construction workers are at high risk of contracting COVID-19 because they have to work in groups and are often unable to maintain sufficient physical distance. Additionally, health and sanitation facilities at project sites may be inadequate to prevent the spread of the virus.
2. Project Productivity: Social distancing and health protocols may cause a decrease in productivity as workers must comply with additional safety measures. This can extend the duration of the project and increase costs.
3. Material Supply: The COVID-19 pandemic has disrupted global supply chains, making it difficult to get construction materials on time. Material delivery delays can cause project implementation delays.
4. Project Costs: Project costs may increase due to additional costs to comply with health protocols, delays in material delivery, and reduced productivity. Wibowo [5] stated that project costs during the pandemic could increase significantly due to these factors.

Risk Management in Construction Projects

Risk management is a systematic process for identifying, analyzing, and responding to risks that may affect the achievement of project objectives. According to Alali et al. [6], the main goal of project risk management is to reduce the impact of risk on project success and maximize potential profits.

Project risk management involves several key steps:

1. Risk Identification: Identify all potential risks that may affect the project. Risks can come from various sources, such as technical, environmental, social, and economic.
2. Risk Assessment: Evaluate risks based on their probability of occurrence and impact on the project. Risk assessment can be done on a qualitative or quantitative scale.
3. Development of a Mitigation Plan: Create measures to reduce or minimize the impact of risks. Mitigation plans should include clear prevention and response measures.
4. Risk Monitoring: Throughout the project, continuously monitor risks to ensure that mitigation plans are working and make adjustments if necessary.

Regression Analysis

Regression analysis is a statistical technique that examines the relationship between two or more variables. This research uses regression analysis to test the influence of independent variables (lockdown level, COVID-19 spread level, and government policy) on dependent variables (cost, quality, and time).

According to Sugiyono [7], regression analysis can help researchers understand the extent to which independent variables influence dependent variables and identify the most influential factors. Regression analysis can also be used to make predictions about a dependent variable based on the values of the independent variables.

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The general formula for the multiple linear regression equation is:

$$y=a+b_1x_1+b_2x_2+b_3x_3+e \quad \text{..... (1)}$$

which is:

y = dependent variable (cost, quality, time)
a = intercept
b_1, b_2, b_3 = regression coefficients for each independent variable
x_1, x_2, x_3 = independent variables (level of lockdown, level of spread of COVID-19, government policy)
e = error term

Fault Tree Analysis (FTA)

FTA is a risk analysis method used to identify and evaluate risk factors that contribute to the occurrence of an undesirable event (top event). According to Ericson II [8], FTA involves creating a fault tree structure that shows the relationship between basic events and intermediate events that cause the top event to occur.

The steps in the FTA include:

1. Top Event Identification: Identify and categorize the undesirable events for analysis.
2. Identification of Intermediate Events: Identifying intermediate events that contribute to the occurrence of top events.
3. Identify Basic Events: Identify the fundamental events that cause intermediate events to occur.
4. Creating a Fault Tree Structure: Create a diagram that shows the relationship between basic events, intermediate events, and top events.
5. Probability Data Collection: Collect information on the probability of basic events occurring.
6. Fault Tree Quantification: This method calculates the probability of top events occurring based on the probability of basic events.
7. Evaluation of Results: Evaluate FTA results to identify key risk factors and develop mitigation strategies.

The risk probability scale can be grouped as follows:

- Very Low (0.01 - 0.1)
- Low (0.1 - 0.3)
- Medium (0.3 - 0.5)
- High (0.5 - 0.7)
- Very High (0.7 - 1.0)

Refer to Zio [9] the output probability can be calculated by:

$$P_{OR} = 1 - \prod_{i=1}^{n}(1\text{-}P^{i}) \quad \ldots. (2)$$

which is:

P_{OR} = output probability of the OR gate.
P^{i} = basic event probability of i.
n = the number of basic events connected to the OR gate.
$\prod_{i}^{n}$ = the product of all basic event probabilities i.

II. RESEARCH PROGRAM

Types of Research and Samples

This study employs a quantitative methodology that incorporates regression analysis and Fault Tree Analysis (FTA). A dataset was collected from 13 road development projects in East Lombok Regency in 2021, with a subset of 7 projects selected as samples using purposive sampling approaches. The researchers opted for this methodology to evaluate the influence of pandemic-related independent variables on the measured dependent variables.

The selection of the example projects was determined by many criteria, such as the size, nature, location, and completion state of each project. The purpose of this action was to guarantee that the chosen sample accurately represents the whole population of road development projects in East Lombok Regency. Furthermore, the process of sample selection considers the accessibility of the necessary data for conducting regression analysis and FTA.

Data Collection Instruments and Techniques

Data was collected through questionnaires, observations, interviews, and documentation studies. Project stakeholders received questionnaires to gather data on research variables. Observations were carried out to obtain direct data from the field, while interviews were conducted with experts and related parties to obtain more in-depth information. Documentation studies are used to complement data obtained from questionnaires, observations, and interviews. Validity and reliability tests were carried out to ensure the accuracy of the research instruments.

This research uses a questionnaire with several parts: project identification, respondent identification, and assessment of research variables. The questionnaire was designed for each section to gather specific information required for regression analysis and FTA. In addition, the questionnaire incorporates a filling guide to facilitate respondents in providing precise and pertinent responses.

Data analysis

A regression analysis was conducted to examine the association between independent variables (lockdown level, COVID-19 spread level, government policy) and dependent variables (cost, quality, time).

Fault Tree Analysis (FTA) is a method employed to discover and assess risk variables that impact the efficiency of project execution. Regression analysis is a useful tool for determining the degree to which independent variables impact dependent variables. On the other hand, FTA (Fault Tree Analysis) offers a comprehensive assessment of the specific risk factors that lead to a decrease in project performance. The process of regression analysis was conducted utilizing the SPSS statistical program. The process of regression analysis involves several steps: data collecting, data processing, verifying regression assumptions, estimating regression parameters, and evaluating the results. Regression analysis results are utilized to ascertain the importance of the independent variable's impact on the dependent variable and to identify the most relevant risk variables. The method of Fault Tree Analysis (FTA) entails the identification of primary events, intermediate events, and basic events, the construction of a fault tree structure, the collection of probability data, the quantification of the fault tree, and the evaluation of the results. FTA data are utilized to identify the primary risk variables that contribute to diminishing the efficiency of project execution and to develop effective ways for mitigating them.

III. RESULTS AND DISCUSSION

Regression Analysis

The regression analysis findings indicate that the degree of lockdown, the transmission of COVID-19, and government policy do not exert a noteworthy impact on the cost and quality of development. However, they do have a substantial influence on the duration of project implementation. The findings indicate that the COVID-19 pandemic has a greater influence on the duration of project completion compared to its effect on cost and quality. The stringent lockdown measures and government policies that restrict movement and project operations result in substantial delays in the execution of road infrastructure projects. The Table 1. displays the outcomes of the regression analysis for each dependent variable:

Table 1. Results of regression analysis for each dependent variable.

Dependent Variable	Independent Variable	Regression Coefficient	t-count	p-value
Cost	Lockdown Level	0.061	0.437	0.664
	COVID-19 Spread Rate	-0.352	-2.055	0.046
	Government Policy	-0.168	-1.386	0.173
Quality	Lockdown Level	-0.027	-0.171	0.865
	COVID-19 Spread Rate	-0.051	-0.268	0.790
	Government Policy	-0.343	-2.511	0.016
Time	Lockdown Level	0.265	5.367	0.000
	COVID-19 Spread Rate	0.347	5.750	0.000
	Government Policy	0.180	4.214	0.000

The regression results show that only the time variable has a significant relationship with the level of lockdown, the spread of COVID-19, and government policy. Contractors and the government implemented a compensation mechanism to maintain the stability of project costs and quality during the pandemic, which may have led to the absence of a significant impact on costs and quality.

FTA Analysis

The four primary risk factors determined by FTA are:

1. Material Supply Chain Disruption: Probability 0.84 (very high category). Transportation restrictions and supplier factory closures limited access to construction materials, causing this disruption.
2. Decreasing in labor availability and productivity: Probability 0.56 (medium category). Worker absenteeism due to illness or self-isolation, along with restrictions on worker mobility, caused this decrease.
3. Coordination and Communication Disorders Among Project Teams: Probability 0.72 (high category). Dependence on unreliable communications technology and a lack of access to clear and up-to-date information cause this disruption.
4. Increased Occupational Health and Safety Risks: Probability 0.97 (very high category). Lack of adequate health and sanitation facilities and non-compliance with health protocols cause this risk.

The results of calculating the risk probability for each intermediate event can be visualized in Fig. 1.

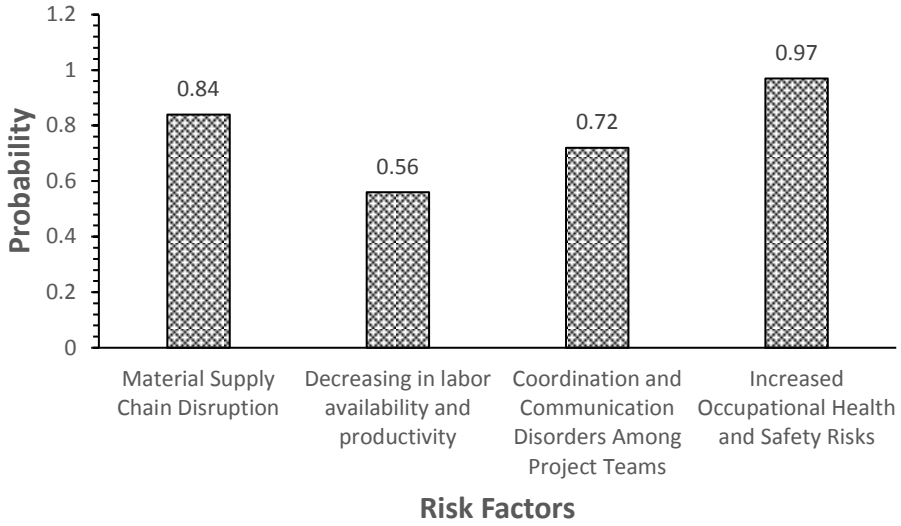

Fig. 1. Intermediate event risk probability diagram

The overall probability of a reduction in project implementation effectiveness is extremely high (0.99), indicating that the negative impacts of the pandemic on road infrastructure projects are almost certain to occur if there are no appropriate mitigation measures.

IV. CONCLUSION

Based on the results of research conducted using the regression and FTA analysis, the following conclusions can be drawn:

1. There is no significant relationship or influence between the level of lockdown, the level of spread of COVID-19, and government policy on the cost and quality of development, but there is a significant relationship and influence on construction time.
2. COVID-19 significantly affects the construction time variable with indicators (duration of construction, level of effectiveness, and schedule changes), which is why it serves as a reference for identifying risk factors in development.
3. There are several solutions obtained to anticipate constraints and obstacles in development, including: a) further increase the supervision of ongoing work; b) implementing a new rescheduling of the existing planned schedule by prioritizing the sources of problems that have been analyzed; c) delays in the disbursement of funds can be overcome by preparing data earlier regarding disbursement requirements so that delays in disbursement can be anticipated earlier.

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