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Implementation of Regression Approach and Fault Tree Analysis (FTA) to Evaluate the Impact of COVID-19 Pandemic's on Cost, Quality, and Time in Road Development in East Lombok, Indonesia

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***Abstract*— *The emergence of the COVID-19 pandemic in late 2019 has had a significant impact on various industries, particularly the road infrastructure construction industry. The objective of this study is to evaluate the impact of the COVID-19 epidemic on the costs, quality, and timeline of road infrastructure projects in East Lombok Regency throughout the year 2021. This will be achieved by utilizing a regression methodology and Fault Tree Analysis (FTA). This study employs data from 13 road construction projects carried out in East Lombok Regency in 2021 as the population. From this population, 7 projects are chosen as samples using the Purposive Sampling technique. A regression analysis was used to investigate the relationship between independent variables related to the pandemic (such as the severity of lockdown measures, the rate of COVID-19 transmission, and government regulations) and dependent variables (including cost, quality, and construction time). The regression analysis conducted in the simultaneous test (F Test) shows that the Lockdown Level, the Level of Spread of COVID-19, and Government Policy together have no significant impact on the Cost and Quality of Road Infrastructure Development. This result is derived from the comparison of the calculated F value with the F table value, where the calculated F value is found to be lower than the F table value. Additionally, the significance level used in this comparison is greater than 0.05. However, these three variables have a significant influence on the Road Infrastructure Development Time variable, as indicated by the estimated F value being higher than the F table value and the significance threshold being smaller than 0.05. FTA analysis is utilized to identify risk variables in the variable of development time, particularly those that have a significant impact based on the results of the regression analysis. The FTA analysis, employing top-even reduction as a representative variable for construction time, identified four primary risk variables that had an adverse impact on the effectiveness of project implementation. The factors encompass a high likelihood (0.84) of disruption in the supply chain of materials, a moderate likelihood (0.56) of reduced availability and productivity of labor, a high likelihood (0.72) of disruption in coordination and communication among project teams, and a very high likelihood (0.97) of heightened occupational health and safety risks. The probability of a decline in the efficiency of project execution is 0.99, placing it in the extremely high range. This indicates a high probability of the event taking place. According to the results of this study, several strategies are recommended to mitigate the impacts of the pandemic. The solutions encompass diversifying the supply sources, improving worker knowledge and training, employing communication technologies for virtual meetings, and establishing stringent health protocols. These strategies are anticipated to improve the sustainability and effectiveness of road infrastructure improvement 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.*

I. INTRODUCTION

The COVID-19 outbreak has greatly disrupted road infrastructure construction in East Lombok Regency. The introduction of strict social distancing policies and health procedures has a direct impact on project delivery, leading to increased costs and posing management issues. The pandemic has severely affected the construction industry, which is an important part of economic growth. The COVID-19 epidemic has resulted in difficulties such as project delays, escalated expenditures, and diminished work quality.

As per the World Health Organization [1], this global epidemic has significantly disrupted health, economic, and social systems worldwide. Multiple industries, such as construction, have encountered the task of sustaining their activities while prioritizing worker safety and complying with rigorous health requirements.

The COVID-19 epidemic has not only affected the accessibility of workforce and resources, but also the manner in which individuals carry out tasks and engage with one another at the project location [2]. The implementation of social constraints and health precautions, such as adhering to physical distancing and wearing face masks, has altered the operational dynamics of labor in the field [3]. Moreover, disturbances in worldwide supply chains result in the postponement of material and equipment shipments, leading to a direct influence on project timelines and expenses. Previously, stakeholders may not have placed a high importance on utilizing digital technology for communication and project coordination. However, the epidemic forced them to adapt and make the necessary changes.

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

The COVID-19 pandemic has had a significant impact on the building sector. Parinduri and Parinduri [4] identify three significant areas in which the pandemic has had an influence on the building sector:

1. Worker Health and Safety: Construction workers face a heightened susceptibility to contracting COVID-19 because to

their need to work in close proximity and their limited ability to maintain adequate physical distancing. In addition, the health and sanitation facilities at project sites may be insufficient to effectively prevent the transmission of the virus.
2. Project Productivity: The implementation of social distancing and health protocols may lead to a decline in productivity due to the necessity for personnel to adhere to additional safety measures. This can prolong the time of the project and escalate costs.
3. Material Supply: The COVID-19 epidemic has caused significant disruptions to worldwide supply chains, resulting in challenges in obtaining building materials within the expected timeframe. Delays in the supply of materials might result in delays in the implementation of a project.
4. Project Costs: The costs of the project may rise as a result of increased expenses required to adhere to health rules, delays in the delivery of materials, and decreased productivity. According to Wibowo [5], the project expenses may experience a substantial increase during the pandemic as a result of these reasons.

Risk Management in Construction Projects

Risk management is a methodical procedure for identifying, examining, and addressing any risks that could impact the attainment of project goals. Alali et al. [6] state that the primary objective of project risk management is to minimize the negative effects of risk on project success and optimize potential financial gains.

Project risk management encompasses a series of essential stages:
1. Risk Identification: Identify all potential hazards that may impact the project. There are multiple sources from which risks can arise, including technological, environmental, social, and economic factors.
2. Risk Assessment: Assess the risks by considering their likelihood of happening and the extent of their influence on the project. Risk assessment can be conducted using either a qualitative or quantitative approach.
3. Formulation of a Mitigation Plan: Establish strategies to diminish or mitigate the consequences of hazards. Mitigation plans should have explicit measures for both prevention and reaction.
4. Risk Monitoring: Consistently evaluate potential hazards during the project to verify the effectiveness of risk reduction strategies and make any necessary modifications.

Regression Analysis

Regression analysis is a statistical method used to investigate the correlation between two or more variables. This study employs regression analysis to examine the impact 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 is a useful tool for researchers to assess the degree to which independent variables impact dependent variables and find the most relevant components. Regression analysis can be employed to forecast the values of a dependent variable by considering the values of the independent variables.

The multiple linear regression equation can be expressed using the general formula:

$$y=a+b1x1+b2x2+b3x3+e$$

which is:
y = dependent variable (cost, quality, time)
a = intercept
b1, b2, b3 = regression coefficients for each independent variable
x1, x2, x3 = independent variables (level of lockdown, level of spread of COVID-19, government policy)
e = error term

Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a risk assessment technique employed to identify and assess the risk factors that lead to the occurrence of an undesired event, often known as the top event. Ericson II [8] defines Fault Tree Analysis (FTA) as the process of constructing a fault tree structure that illustrates the connection between basic events and intermediate events that lead to the occurrence of the top event.

The FTA consists of the following steps:
1. Event Identification: Identify and categorize the undesired events for analysis.
2. Identification of Intermediate Events: The process of recognizing and determining the intermediate events that play a role in causing the top events to happen.
3. Determine Fundamental Events: Identify the primary events that trigger the occurrence of intermediate events.
4. Constructing a Fault Tree Hierarchy: Generate a graphical representation that illustrates the interconnection of fundamental events, intermediary events, and overarching events.
5. Probability Data Collection: Gather data on the likelihood of fundamental events taking place.
6. Fault Tree Quantification: This approach determines the likelihood of top events happening by considering the probability of basic events.
7. Results Evaluation: Assess FTA results to identify crucial risk variables and formulate measures for risk reduction.

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:

$$P_{OR} = 1 - \prod_{i=1}^{n}(1-P^i)$$

which is:
P_OR = output probability of the OR gate.
Pi = basic event probability of i.
n = the number of basic events connected to the OR gate.
∏_i^n = the product of all basic event probabilities i.

II. Research Program

Types of Research and Samples

This study utilizes a quantitative methodology that integrates regression analysis and Fault Tree Analysis (FTA). In 2021, a dataset was gathered from 13 road development projects in East Lombok Regency. From this dataset, a subset of 7 projects was chosen as samples using purposive sampling methods. The researchers chose this methodology to assess the impact of pandemic-related independent variables on the assessed dependent variables.

The selection of the example projects was based on various criteria, including the project's size, type, location, and completion status. The objective of this operation was to ensure that the selected sample is a true and representative reflection of the entire population of road construction projects in East Lombok Regency. Moreover, the method of sample selection takes into account the availability of the required data for doing regression analysis and FTA.

Data Collection Instruments and Techniques

Data was gathered by questionnaires, observations, interviews, and documentation analyses. Questionnaires were distributed to project stakeholders in order to collect data on research variables. Field observations were made to gather firsthand data, while interviews were undertaken with specialists and relevant stakeholders to acquire more comprehensive information. Documentation studies are employed to supplement data acquired from questionnaires, observations, and interviews. Validity and reliability tests were conducted to ascertain the precision of the research tools.

This study employs a questionnaire comprising multiple sections, including project identification, respondent identification, and evaluation of research factors. The questionnaire was specifically prepared for each component to collect the necessary information needed for regression analysis and FTA. Furthermore, the questionnaire includes a comprehensive guide to assist responders in offering accurate and relevant answers.

Data analysis

A regression analysis was performed to investigate the relationship between independent variables (lockdown level, COVID-19 spread level, government policy) and dependent variables (cost, quality, time). Fault Tree Analysis (FTA) is a technique used to identify and evaluate risk factors that affect the effectiveness of project implementation. Regression analysis is a valuable tool for quantifying the extent to which independent variables influence dependent variables. However, FTA (Fault Tree Analysis) provides a thorough evaluation of the precise risk elements that contribute to a decline in project performance. The regression analysis was performed using the SPSS statistical software. The regression analysis process has numerous steps, including data collection, data processing, verification of regression assumptions, estimation of regression parameters, and evaluation of the results. Regression analysis results are used to determine the significance of the independent variable's influence on the dependent variable and to identify the most pertinent risk variables. Fault Tree Analysis (FTA) involves identifying primary events, intermediate events, and basic events, constructing a fault tree structure, collecting probability data, quantifying the fault tree, and evaluating the results. FTA data is used to identify the main risk factors that contribute to reducing project execution efficiency and to design effective strategies for mitigating them.

III. Results and Discussion

Regression Analysis

The regression analysis results suggest that the level of lockdown, the transmission of COVID-19, and government policy do not have a significant influence on the cost and quality of development. Nevertheless, they exert a significant impact on the length of time it takes to complete a project. The results suggest that the COVID-19 pandemic has a more significant impact on the time it takes to complete a project compared to its effects on cost and quality. The severe lockdown measures and government policies that limit movement and project activities lead to significant delays in the implementation of road infrastructure projects. Table 1 presents the results of the regression analysis for each dependent variable.

TABLE I. 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 analysis reveals that only the time variable exhibits a statistically significant correlation with the level of lockdown, the propagation of COVID-19, and government policy. Contractors and the government established a compensation mechanism to ensure the stability of project costs and quality during the epidemic, perhaps resulting in no substantial impact on costs and quality.

A. *FTA Analysis*

The FTA has identified four main risk factors:

1. Material Supply Chain Disruption: Probability 0.84 (classified as very high). This disruption was caused by transportation limitations and the shutdown of supplier factories, which hampered the availability of construction materials.
2. Labor availability and productivity are expected to decline,

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with a probability of 0.56, placing it in the medium group. This decline was driven by worker absence resulting from illness or self-isolation, as well as limits on worker movement.
3. Coordination and communication disorders are prevalent among project teams, with a probability of 0.72, placing it in the high category. This disruption is caused by a reliance on faulty communications technology and a lack of access to accurate and current information.
4. Heightened Occupational Health and Safety Hazards: Probability 0.97 (classified as extremely high). This risk arises due to insufficient health and sanitation infrastructure and failure to adhere to health regulations.

Figure 1 displays the visual representation of the calculated risk probability for each intermediate event.

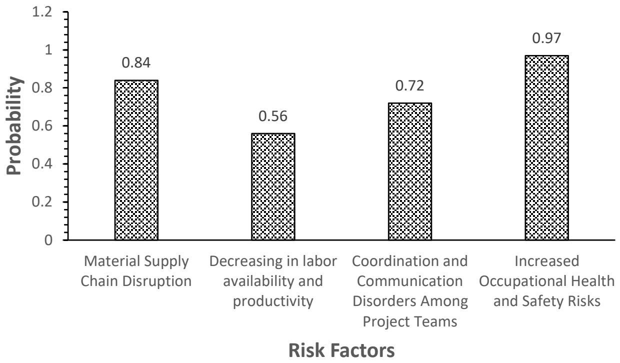

Fig. 1. Intermediate event risk probability diagram

The chance of a decrease in project implementation effectiveness is exceedingly high (0.99), suggesting that the adverse effects of the pandemic on road infrastructure projects are highly likely to occur in the absence of suitable mitigating measures.

IV. Conclusion

The conclusions that may be obtained from the research, which utilized regression and FTA analysis, are as follows:

1. There is no discernible correlation or impact between the extent of lockdown measures, the extent of COVID-19 transmission, and government policies on the cost and quality of development. However, there is a notable correlation and impact on construction time.
2. COVID-19 has a strong impact on the construction time variable, which includes indications such as the duration of construction, level of effectiveness, and schedule adjustments. This makes it useful for identifying risk factors in development.
3. To anticipate constraints and obstacles in development, there are several solutions that can be implemented. These include: a) intensifying supervision of ongoing work; b) implementing a new rescheduling of the planned schedule by prioritizing the sources of analyzed problems; c) preparing data earlier regarding disbursement requirements to anticipate delays in the disbursement of funds.

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