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Research Paper

Delay Factors in Late Implementation of Sidoarjo – Malang City Limit Road and Bridge Preservation Project

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ABSTRACT : *Road and bridge infrastructure development has a fundamental role in driving economic growth, enhancing interregional connectivity and improving the quality of life. However, many infrastructure construction projects in Indonesia often face challenges during their implementation, particularly in the early stage that crucial for the overall success of the project. One such project that has encountered problem is the Sidoarjo-Malang City Limit Road and Bridge Preservation Project in East Java Province. This study aims to identify the factors causing delays in this project and propose mitigation solutions that can be implemented to improve project management in the future.*
The method used in this study was a quantitative approach with analysis using the Fault Tree Analysis method, the result showed that technical factors, project management, and external factors contributed significantly to the delay with a very high probability. There are nine factors causing the delay categorized as highly significant while several other factors such as damage by third parties and delays in equipment procurement were less significant.

KEYWORDS: *Fault Tree Analysis, Road and Bridge Infrastructure, Project Delay.*

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I. INTRODUCTION

The development of road and bridge infrastructure plays a fundamental role in driving economic growth, facilitating public mobility and supporting equitable development across regions. In Indonesia, the infrastructure sector is the key focus from National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional/*RPJMN) to improve inter-regional connectivity and accelerate goods and service distribution. Robust infrastructure has been proven able to improve the logistics efficiency and regional competitiveness where ultimately contributing to improved quality of life for the community. [1]

Inadequate planning and supervision become dominant factors that obstruct the success of construction projects. Sari stated that no regular yield analysis and the discrepancy between the S-curve, contract documents, and progress reports lead to inconsistent information and hinder a rapid decision-making. This demonstrated the importance of integrating project documents and regular reporting to enable management to conduct effective evaluations and improvements. [2]

During implementation of this project, significant deviations from the initial plan indicated a decrease in work progress which brings direct impact of delays in the initial stage of the project. These delays are not only disrupted the implementation schedule but also had implications for operational efficiency and overall project progress. Failure to identify and address delays early on make the field condition even worse which ultimately leading to cost increases and uncontrolled extensions of the implementation time.

Therefore, an in-depth analysis of the factors causing delays is necessary, in particular for those related to the roles of each party: the contractor, the supervising consultant, and the project owner. More intensive and synergistic coordination between the Ministry of Public Works and Public Housing, the supervising consultant, and the contractor is key for ensuring the mitigation strategies can be implemented effectively. These strategies include improving work procedures, adjusting the planning schedule and implementing preventive measures to minimize the risk of delays in subsequent stages. By implementing these findings and corrective measures, it is expected that risk management and project implementation efficiency can be significantly improved until the work implementation reach the 70th week.

So far, discussion related to Delay factors in Sidoarjo-Malang City Limit Road and Bridge Preservation Project have not been carried out by many researchers, therefore the study problems in this research are: (1) What are the main factors that cause delays in the implementation of the Sidoarjo – Malang City Limit Road and Bridge Preservation Project? (2) to what extent is the significance level of each factor causing delays in the Sidoarjo – Malang City Limit Road and Bridge Preservation Project? (3) how is the contribution of risk of failure from the causal factors as seen through the Fault Tree Analysis method?

II. LITERATURE REVIEW

2.1. Theory of Fault Tree Analysis Method

In analyzing project delay issues, this study draws on project management theory and risk analysis techniques. Some relevant theories to address these issues are:

1. The Project Management Theory: refers to the principles of project management which include planning, organizing, implementing and controlling projects to achieve project objectives through effective and efficient ways. [3]
2. The Risk Analysis Theory: This theory helps identify, assess, and manage risks that can impact the project implementation. The Fault Tree Analysis technique is used to identify and analyze the root causes of project delays. [4]

First, the project management theory serves as the basis understanding of how a project should be planned, organized, implemented and controlled. According to Puspitasari et.al, project management encompasses a series of interrelated processes designed to achieve project objectives through effective and efficient way. In the context of project delays, this theory helps review the extent to which project management stages have been implemented in accordance with principles. Inaccuracy in time planning, deficiency in resource organization, or weak implementation supervision can be early indications of delays. Therefore, project management theory is used not only as normative guideline but also as an evaluation tool for the implementation of the analysed project. [3]

Second, this research also refers to risk analysis theory which focuses on identifying, assessing, and managing risks that able to delay the project success. Risks in construction projects can stem from many internal and external factors such as delays in material procurement, extreme weather, design errors and administrative issues. To unravel and analyse the root causes of delays, a Fault Tree Analysis approach is used. This technique allows researchers to construct a logical structure for a failure or major problem (or delays, in this study), then systematically analyse the causal components into a failure tree diagram. This method allows researchers to identify the most dominant factors and how the causes of delays relate to one another.

By combining project management theory and risk analysis technique through Fault Tree Analysis, this study aims to provide a comprehensive, structured and in-depth understanding of project delay issues. This theoretical approach also provides the basis for developing more targeted recommendations for future project management.

It is a risk analysis method widely used in various fields, especially in engineering and project management, to identify the root cause of failure or problem known as a “Top Event”. This approach is systematic and structured with the main goal of tracing and mapping the root cause of an undesirable event through deductive logic.

The Fault Tree Analysis process begins by determining “Top Event” for the first step as the main incident or failure that becomes the focus of the analysis. Once the “Top Event” is determined, the next step is to identify the ‘main cause’ (Level 1) that directly triggered the incident. This main cause is then further broken down into more fundamental causes (Level 2), or further down to Level 3 or more, until the ‘basic event’ or ‘root cause” is found, which is the most fundamental cause that cannot be further broken down.

During this mapping process, logical symbols such as “AND Gate” and “OR Gate” are used to indicate the relationship between one cause and another. An “AND Gate” indicates that all connected causes must occur simultaneously for the top event to occur, while an “OR Gate” indicates that only one of several causes must occur to trigger the top event. These symbols are then visually depicted in a tree diagram that resembles tree branches leading upwards towards the top event.

One of the main advantages of Fault Tree Analysis is its ability to provide a visual and logical overview of how an event can occur due to a combination of various risk factors. In addition to mapping the causal structure, Fault Tree Analysis also allows the “probability calculation” conducted on the top event. This is done by determining the probability of each root cause occurring, then using a logical combination formula (in accordance with AND/OR gates) to quantitatively calculate the likelihood of the main failure occurring.

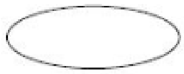
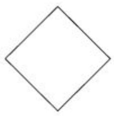
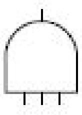
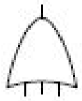
The final stage of the Fault Tree Analysis process is ‘result analysis’ which involves reviewing which factors have the most significant contribution to the Top Event. From these results, researchers or project managers can formulate appropriate and effective risk mitigation strategies, either by eliminating the root cause, reducing the likelihood of the likelihood of the root cause occurring or by strengthening internal control systems to minimize the impact if the risk does occur.

According to Isabela, Fault Tree Analysis is an analytical technique that graphically depics a fault tree, consisting of various logical combinations and parallel relationships between faults. This technique allows user to have clear view of the cause-and-effect relationship between the 'base event" and the "top event". [5]

Thus, Fault Tree Analysis is not only useful for identifying the root cause of a problem, but also as a strategic tool in managerial decision-making related to risk control, mitigation planning and improving overall system reliability. In the graphical model of Fault Tree Analysis, there are three main symbols used: event symbols, gate symbols, and transfer symbols. Various symbols are used to illustrate the failure analysis of existing systems. The following are the types of symbols used in Fault Tree Analysis.

1. The Gate symbol shows how input events lead to output events. In other words, output events are caused by input events that are related to each other in some way.
2. The event symbol is a symbol that depicts an event or occurrence in the system. This symbol is shown in Table 1 below:

Table 1. The event symbol

Event Symbol	Name	Description
	*Intermediate event*	Intermediate events represent events that arise from a combination of failed events that enter a gate.
	*Basic event*	A basic event represents a fundamental failure that does not require further investigation to determine the cause of the event.
	*Diamond*	The diamond image indicates an unpredicted (undeveloped) event. Undeveloped events can be seen in the fault tree and are considered the earliest events that cause damage.
	*AND*	An output event occurs if all input events occur simultaneously.
	*OR*	An output event occurs if at least one input event occurs.

III. RESEARCH METHOD

3.1. Research Location

This research was focused on Sidoarjo-Malang Border area with a particular focus on road and bridge preservation projects. This area was chosen because of the importance of road and bridge infrastructure as a vital part of regional and national connectivity.

3.2. Source Data

In this study, the data source used consist of two main data types, the primary data and secondary data, both of which are very important to support a comprehensive research analysis and conclusions.

1. Primary Data
   Primary data is obtained directly from the field through various data collection techniques that have direct and interactive nature with the research object. The techniques used include:
   a. Interview, the face-to-face interactions with parties directly involved with the implementation of the road and bridge preservation project in the Sidoarjo-Malang City Limit, such as project managers, contractors, field workers, and other stakeholders. These interviews aim to gather in-depth information regarding the project condition, constraints, and factors causing delays.
   b. Questionnaires, which were distributed to relevant respondents to collect quantitative and qualitative data related to their perceptions, experiences, and opinions regarding project implementation.
   c. Direct observation at the project location, which is carried out to obtain a real picture of the work implementation, field conditions, and obstacles encountered during the project.

d. Focus group discussion which involve a number of project actors and experts to obtain various perspectives and clarification on the collected data.
e. A questionnaire, distributed to relevant respondents to collect quantitative data related to their perceptions, experiences and opinions regarding project implementation. In this study, the questionnaire was designed using a five-point Likert Scale to measure respondents' level of agreement with various statements related to factors causing project delays. With the following scale of:

Table 2. Five point of Likert Scale

Score	Category
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

2. Primary Data
   Primary data is obtained directly from the field through various data collection techniques that have direct and interactive nature with the research object. The techniques used include:
   Secondary data was obtained from previously available documentation and literature sources which served as supporting material to strengthen and complement the primary data. Secondary data sources in this study include:
   a. Literature review in forms of books, journal articles, and academic references relevant to the topic or road and bridge preservations and the Fault Tree Analysis method.
   b. Project documents such as shop drawing, time schedule, and progress report related to the work implementation of road and bridge preservation in Sidoarjo-Malang City limit. These documents provide technical and administrative information that essential for a comprehensive understanding of the project conditions and serve as validation of the primary data obtained.

3.3. Jeffreys's Amazing Statistics Program Data Analysis

Data Input: The questionnaire data was entered into the Jeffreys' Amazing Statistics Program worksheet according to the predetermined variables. Reliability Test: Used to measure the consistency of the questionnaire data using Coefficient Alpha, where an α value ≥ 0.7 indicates sufficient reliability of the instrument. Descriptive Analysis: Used to determine the frequency distribution, mean value, and standard deviation of each questionnaire item.

3.4. Data Analysis by Fault Tree Analysis Method

Data analysis technique is a method used to process the research data, and data analysis in this study is carried out qualitative in a descriptive format using the Fault Tree Analysis method with the working stages of the Fault Tree Analysis method:

1. Identify activities causing project delays.
2. Determination of Top Event/Main Cause to be further identified.
3. Begin identifying intermediate and basic events that contribute to project delays and determine the use of logic gates between events in the fault tree.

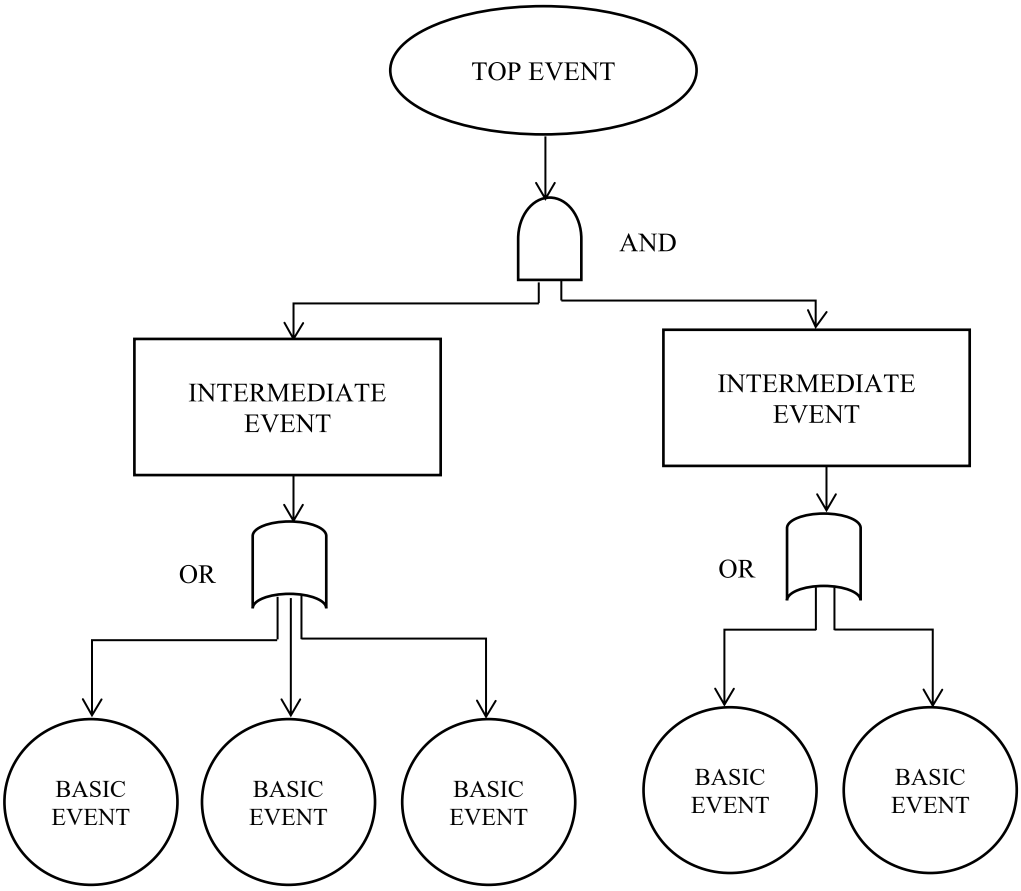


Figure 1. Theory of Diagram Fault Tree Analysis method

IV. RESULT AND DISCUSSION

4.1. Delya Analysis by Fault Tree Analysis Method

The top event in this study was the delay in implementation of the Sidoarjo-Malang City Limit Road and Bridge Preservation Project. The top event was the end result of a combination of several previously identified causes. By employing the Fault Tree Analysis method, these causes were logically connected to demonstrate about how the combination of many failures could trigger project delays.

To trace the root causes of delays in a systematical way, a Fault Tree Analysis approach is used. It is a deductive analysis method used to identify and describe the relationships between various causes of failure until the Top Event or the Main event is reached. In this context, the Top Event being analyzed is the delay in the project implementation.

Fault Tree Analysis plays a crucial role in identifying and analyzing causes of project delays in a systematical way. This method uses a deductive approach to illustrate the relationship between many causal factors that lead to a Top Event or main incident, in this study, the project delays. Fault Tree Analysis is built on three hierarchical levels, allowing a gradual identification of causes from macro causes to more specific factors could happen. In its implementation, Fault Tree Analysis calculates the probability of delay based on each cause category such as technical variables, project management, external factors, contracts, and natural and force majeure, using a combined formula in the "OR Gate". The calculated probabilities help to identify the riskiest factors and provide a clear picture of areas that should be prioritized for further handling. With the results of this analysis, the project team can establish more effective mitigation strategies, focus resources on causal factors with high probability, and accelerate decision-making to reduce the risk of further delays. Fault tree analysis, therefore, serves as a tool for mapping root causes, determining action priorities and assisting in more efficient project management, ensuring smooth implementation and avoiding budget waste.

The Fault Tree Analysis structure is built on three hierarchical levels, allowing for the gradual identification of causes from the macro level to the most specific factors can be identified. The fault tree analysis structure is stated in the following:

1. Level 1: Delay of Bridge and Road Preservation Project
2. Level 2: Main cause (Intermediate events):
   a. Technical variable
   b. Project management variable
   c. External variable
   d. Contract
   e. Nature and force majeure
3. Level 3:
   a. Low productivity level from the workers [6]
   b. Hotmix production requires long time
   c. Maximum mixing capacity only 40 zac/24 hours
   d. Asphalt pump often gets clogged because plastic material unable to crush
   e. Material delivery from Central Java often late
   f. Supplier of buton asphalt only one
   g. BBPJN evaluation requires a long time (approximately 30 days)
   h. Decision making from project owner is too late
   i. Bad weather which causes delay in material mobilization process [3]

By these structures, the Fault Tree Analysis helps to identify the key problem nodes that must be addressed strategically to prevent further delays and reduce the potential budget waste. To calculate the combined probabilities on the OR Gate, use the following formula of:

$$\text{Pcombined} = 1 - \prod_{i=1}^{n} (1 - Pi)$$

Where:
P_i = basic probability from event nu-i
n = number of event in category
The probability calculation per category:

Category A – Technical Variable": ["F3", "F4", "F5"]:
P_A = 1-(1-0,44)(1-0,43)(1-0,45)
= 0.824

Category B – Project Management Variable ": ["F13", "F14"]:
P_B = 1-(1-0.45)(1-0.43)
= 0.686

Category C – External Variable": ["F20", "F22"]
P_C = 1-(1-0.44)(1-0.45)
= 0.692

Category D – Contract Variable ": ["F25"]
P_D = 1-(1-0.45)
= 0.450

Category E – Nature Variable and Force Majeure ": ["F32"]
P_E = 1-(1-0.44)
= 0.440

Total Probability (Top Event) – Project Delay:
P_{top} = 1-(1-P_A) (1-P_B) (1-P_C) (1-P_D) (1-P_E)
= 1-(1-0.824)(1-0.686)(1-0.692)(1-0.450)(1-0.440)
= 0.994

The probability of project delay based on Fault Tree Analysis is 99.39%, indicating that delays are highly likely if the idenfied causal factors are not addressed immediately. This underscores the urgency of corrective action, particularly in the areas of material procurement, production, and logistics, as well as the project evaluation and management processes.

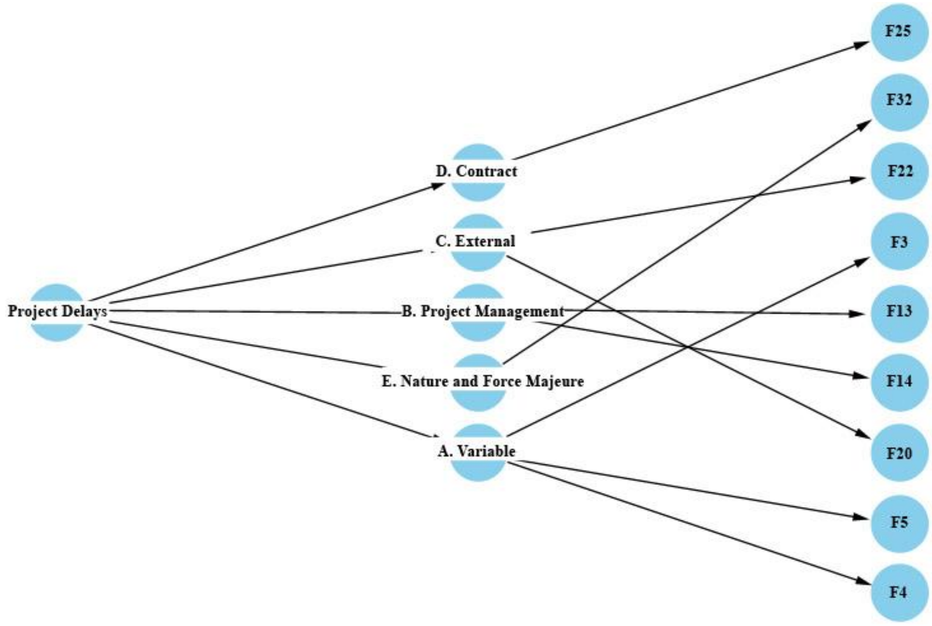


Figure 2. Diagram Fault Tree Analysis

4.2. Discussion

Delays in the implementation of infrastructure projects, in particular to road and bridge preservation are a complex and multidimensional problems. In this study, the identification of main factors causing delays was carried out by distributing questionnaires to 30 respondents consisting of contractors, supervisory consultants, and project owners. Based on the results of the questionnaire data recapitulation, it was found that several factors had a dominant influence on project delays. The most prominent factor was F5; the limited mixing capacity of pure asbuton which only reached 40 sacks per 24 hours, with the highest average score of 4.61. Followed by F3 (low labor productivity), F25 (delayed decision-making by the project owner), F4 (the hotmix production process takes a long time), and F13 (the asphalt pump is often blocked), each with average score between 4.48 and 4.52. These factors reflect technical, operational, and managerial issues that directly affect the smooth implementation of the project in the field.

To understand the significance level of each causal factor, the measurements were conducted by using average assessment score. Factors with an average score above 4.00 were categorized as highly significant factor. Of the 33-factor analysed, seven factors fell into this category. Meanwhile, several factors were deemed less significant because they receive an average score below 3.00, such as F30 (damage caused by a third party), F11 (delay in equipment procurement) and F21 (supplier lacks a Job Mix Formula).

The result of this study indicate that project delays are more influenced by specific technical and administrative obstacles, rather than by general factors such as labor condition or uncontrollable external factors. This indicates the factors such as technical problems in material procurement, constraints in the production process, and lengthy evaluations are the main causes of delays, compared to more general and less controllable factors such as weather condition or labor availability.

In comparison to the previous research, these results align with those results of Manus et al., who identified contract changes, poor scheduling and slow design review processes as key factors contributing to delays. This study places greater emphasis on administrative barriers and changes in project scope that impact project progress. [4]

However, these findings differ slightly from Tyas and Waskito findings that indicated the bad weather condition and delays in land acquisition were the main inhibiting factors. These findings place greater emphasis on external factors beyond the project team's direct control. [7]

Payapo et.al., identified funding, labor, and construction materials as dominant factors in delays, which can include technical and administrative obstacles but also include financial and human resource factors, which are slightly broader and cover general aspects that can affect the speed of project completion. [8]

Overall, although this study indicates the technical and administrative barriers are more influential, the previous research has also found that various factors, both technical, administrative, and external, contribute to project delays. Thus, the result of this study is in line with many previous studies that show the project delays can be influenced by various interacting factors, although the main focus of this study tends to be more specific and controllable obstacles within the project scope.

To strengthen the quantitative analysis results from the questionnaire, the Fault Tree Analysis approach was used as a tool to map the logical relationship between causal factors and the main event (Top Event) namely the project delay. In the Fault Tree Analysis structure, factors are categorized into five main groups of technical variables, project management, external factors, contracts, nature and force majeure. Each category is analysed through the OR Gate model which produces the probability of contributing to the delay. The calculation results show that the probability of the Top Event reaching 0.994 or 99.39 % if all significant factors are left unmitigated.

It showed how high the risk of delay in the project would be if there are no control measures taken. By using Fault Tree Analysis, the analysis results show that researchers can assess not only the individual strength of each causal factor, but also their collective contribution to the failure of the project system. By using the Fault Tree Analysis method, factors causing delay are analysed both separately and in their interactions. This allows for a more comprehensive understanding of how the combination of interrelated factors can increase the risk of delay and influence the overall project failure.

The findings from Fault Tree Analysis become the basis for formulating more effective and targeted mitigation strategies. These strategies are based on result analysis conducted using the Fault Tree Analysis method, as well as research from previous research that relevant to this study. For example, in technical variable category, it is recommended to increase monitoring of quality materials and equipment used in the project. This aligns with the findings of Manus et al., which showed that inadequate material quality and work tools can cause significant delays in road preservation projects. Furthermore, research by Tyas and Waskito also identified the importance of improving the work scheduling and inter-team coordination to mitigate the impact of technical obstacles on project success. Therefore, increasing production capacity and quality, as well as improving material procurement procedure, are targeted mitigation measures to address technical obstacles that impact project implementation time. It is recommended to increase the capacity of the Asbuton mixing facility and conduct regular maintenance on production equipment, particularly the asphalt pump. [4,8]

Overall, the combination of quantitative analysis through questionnaires and logical modelling using Fault Tree Analysis provides a more comprehensive picture of the causes of project delays. This approach not only identifies dominant factors but also classifies the level of contribution based on the structure of relationships between components. This enables more targeted decision-making in formulating technical and administrative policies, while also serving as a guideline for planning similar projects in the future. Thus, Fault Tree Analysis serves not only as a diagnostic tool but also as a strategic instrument in managing construction project risks.

V. CONCLUTION

According to the result analysis of Fault Tree Analysis approach, there are several findings obtained in this study as concluded into:

1. The main factor causing delays in the implementation of Sidoarjo-Malang City Limit Road and Bridge Preservation Project are: low labor productivity, long time in hotmix production, delays in material delivery, and technical problems such as limited mixing capacity and asphalt pumps that often blocked.
2. The level of significance of each factor causing delays shows nine very significant factors with an average value above 4.00 while several other factors such as damage by third parties and delays in equipment procurement are classified as less significant with an average value below 2.00.
3. The result of the Fault Tree Analysis reinforces the questionnaire results by grouping the factors causing delays into five main categories: technical variables, project management, external factors, contracts, and natural and force majeure, which contribute the highest risk of failure. The five categories contributing the highest risk failure are:
    a. Technical variables with a probability of delay of 82.4%
    b. Project management variables with a probability of 68.6%
    c. External variables with a probability of 69.2%
    d. Contract variables with a probability of 45%
    e. Nature and force majeure with a probability of 44%

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