Project Planning of Offshore Pipelines Replacement: Study Case at Offshore North West Java

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Abstract: There are many factors that lead to project delay, for example hurricane, one of weather factors that make it impossible to do work or factors like lack of utilities and construction equipment, delays in purchasing material orders, lack of experienced and skilled human resources in the field, delay costs down to purchase activities on the project. In addition, there are delays in critical activities because they have a large impact on the duration of the project. Therefore, it is necessary to do an analysis by looking for activities that are critical to the project and factors that can cause delays in the new pipeline project because it can endanger the owners and contractors. This study will discuss three factors, i.e. (1) the determination of the critical path, (2) the determination of the root causes that can cause delays, and (3) the risk of over time, of new pipelines replacement project in North West Java, Indonesia. There are 4 indications of delay in this project, which are delay that occurred in June 2018, September 2018, and October 2018. The biggest deviation between the targeted value and the actual value occurred in October 2018, which was 5,05%. This study uses six sigma methods, critical path, fault tree analysis and event tree analysis. The results of fault tree analysis will get the probability value for the top event of the project delay. The results of the event tree analysis will get the risk level of each factor that causes delays. Six sigma results will get to the root of the problem, the value of sigma, and what corrective action is taken.

1 INTRODUCTION

Project implementation must be supported by good project management. The absence of project management will bring about change, unclear goals, non-challenging planning, high risk, poor project quality, more expensive project costs, and delays in improving the project. Project management can be subdivided such as project time management, project human resource management, and project risk management (PMBOK, 2008). The company plans to carry out the offshore pipeline repair and replacement project. This project covers the aspects of engineering, procurement, construction, and installation, called the EPCI project. Pipeline is located 80 - 200 km northeast of Jakarta. The core of this project is to replace pipes that are no longer suitable for use by installing new pipes for pipes that are already damaged. There are three pipelines planned to be replaced, namely:

(i) Pipe A with 12"OD and 1 km length
(ii) Pipe B with10" OD and 7.2 km length
(iii) Pipe C with 8" OD and 7.2 km length

The construction project sector has a high level of responsibility and complexity. All construction projects can be categorized as complex projects. This is caused by a direct relationship between complexity and involves various interredelayd parts that must be managed with regard to conditions of differentiation and interdependence, thus causing construction projects to have high risks (Baccarini, 1996). Based on the explanation in the paragraph above, this project is a complex project because it has three projects with different pipe sizes and lengths. Therefore, this paper will discuss project risks in the form of overtime (project delays) that can have an impact on project cost overruns. Project risk in the form of overtime and

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excess costs must be avoided because it can endanger all parties such as the owner and contractor, for example from the owner will suffer losses because the object of the project cannot operate, so it does not generate profits. On the other hand, the contractor must be responsible for delays and the contractor's good name becomes bad.

Table 1: Indications of Delay in the Development of a New Pipe Replacement Project on Deteriorated Pipelines.

	June 2018	June 2018	Sept 2018	Oct 2018
Planned Value	0,06%	6,35%	40,11%	53,20%
Earned Value	0,00%	5,63%	39,71%	48,15%

Table 1 explains that there are indications of delays in the construction of new replacement pipe projects for damaged pipelines. Indications occurred in June 2018, September 2018, and October 2018. The largest deviation between the planned value and the value obtained occurred in October 2018 at 5.05%. Many factors can make a project experienced delay, for example weather factors that make it impossible to do work or factors of lack of utilities and construction equipment, delays in purchasing material orders, lack of experienced and skilled human resources in the field, delay costs down to purchase activities on the project, in addition, there are delays in critical activities because critical activities have a large impact on the duration of the project.

Therefore it is necessary to analyze the delay by looking for any activities that are critical to the project and factors that can cause overtime. To avoid overtime in this new pipeline project because it could endanger the owner and contractor as explained in the previous paragraph. In this study, we will discuss determining the critical trajectory, determining the root cause or factors that can cause delays, a large risk of delay, and what improvements can be made.

2 BASIC THEORY

2.1 Project Management

Project management is planning, organizing, leading, and controlling company resources to achieve short-term goals that have been determined. Project management has a basic function consisting of managing the scope of work, time, cost, and quality. The key to successful implementation of a project if you can manage these aspects correctly (Samad, 2019).

2.2 Risk

Risk is a combination of the probability of an event and the impact of the event, the impact can be more than one for one event. However, risks are generally seen as negative things such as danger, loss, and other impacts. These impacts and losses is actually a form of uncertainty that should be understood and managed effectively by the project implementer (Szymanski, 2017).

2.3 Critical Path

Critical path is a project management technique that uses only one-time factor per activity. Critical path or critical path is the fastest path in project work, every project included in this path is not given a break / break for the process. Critical path is a path that consists of activities which if delay will result in delay completion of the project Heizer, 2014).

2.4 Six Sigma Analysis

The statistical concept that measures a process that is redelayd to the sigma number, where the closer to 6 the results will be as expected. Six Sigma is a management philosophy that focuses on removing defects by emphasizing understanding, measuring and improving processes (Brue, 2002). Six Sigma has 5 stages, as follows (Larasatie, 2019):

(i) Define

Define aims to identify the process to be improved and determine what resources are needed in project implementation.

(ii) Measure

Measure is an advanced stage of define where at this stage validation of a problem is done by calculating and obtaining numbers that can provide clues about the problem.

(iii) Analyze

At this stage, the cause of the deviation in a project will be investigated with a hypothesis which will then be tested.

(iv) Improve

At this stage, the main factors are ascertained and give new influences so that they get the desired results. The purpose of this stage is to implement a new system so that the project can run more optimally.

(v) Control

Maintain changes that have been made through certain measuring devices so that it can be assessed whether the new system is optimally implemented in the project.

2.5 Fault Tree Analysis

Fault tree analysis is a method to identify and analyze all the factors that might cause a system failure and provide a basis for calculating the probability of a failure event. Unwanted events that are on top (top event) for all root causes that might occur at the bottom. The causative factors are deductively identified, logically arranged and represented using pictures in a tree diagram illustrating the causal factors and their logical relationship to the peak event (ISO, 2009).

2.6 Event Tree Analysis

Event tree analysis is a method used to evaluate processes and events that lead to the possibility of failure. This method is useful in analyzing the consequences arising from failures or unwanted events. The consequences of events are followed through a series of possibilities. By analyzing all possible outcomes, it is possible to determine the percentage of results that lead to both desired and undesirable results (Silvianita et al, 2017).

Event tree analysis is an analysis technique to identify and evaluate the sequence of events in a potential accident scenario after the initial event or initiating event. Event tree analysis uses a visual logic tree structure known as an event tree. The purpose of the event tree analysis is to determine whether the initiating event will develop into a serious accident or whether the event is sufficiently controlled by the safety system and procedures applied in the system design. Event tree analysis can produce many different results from one initial event, and this provides the ability to obtain probabilities for each outcome (Ericson, 2005). Project delay using ETA and Bow Tie Analysis for mooring change replacement can be seen in (Silvianita et al, 2018). and project delay for HRSG has been discussed (Silvianita et al, 2017b).

3 METHODOLOGY

The procedures of the research are as follow:

1. Formulations of Problems

The formulations of the problems are decided as the purpose or the goal of the research.

2. Literature Studies

To support the research itself, literature studies are needed to develop insight and analysis. In this case, the literature needed is as follows:

a. A study about offshore pipeline projects.
b. A study about project management and project delays.
c. A study about critical path methods.
d. A study about six sigma analysis.
e. A study about fault tree analysis
f. A study about event tree analysis.
g. A study about risk matrix

3. Data Collection

Data collection is needed as material to support the research hypothesis. The data corredelay with the evaluation and the current conditions. The data needed are as follows:

a. Pipeline repair and replacement project report data
b. Pipeline repair and replacement project master schedule data
c. General data about the pipeline installation project
d. Make a questionnaire to look for the probability of basic FTA events, pivotal ETA events, and determination of risk matrices.

4. Data Analysis and Discussion

The data that has been collected will be analyzed and discussed:

a. Make network diagrams and find project critical activities using the critical path method.
b. Identification uses 4 stages of six sigma analysis (define, measure, analyze, and improve).
c. Determine the root causes that can cause the project to be delayed by using fault tree analysis.
d. Determine risk by using event tree analysis.
e. Determine the probability of project delay.

5. Results and Conclusions

The results of this study are used as a reference for decision making in planning subsea pipeline projects in the future, so as to advance the performance and smoothness of all underwater pipeline project activities. The flowchart of this paper are shown in Figure 1.

4 ANALYSIS RESULTS AND DISCUSSIONS

4.1 Data Collection

Data collection is the most important thing in project planning because without the complete data planning the project cannot be planned properly. In this study, the following data were obtained from one of the oil and gas company. Data that are needed in this study include work data on project activities, duration of project activities and relationships between the project activities (predecessors).

Table 2: Project Activity, Duration, and Predecessor.

Activity ID No.	Activities	Duration (day)	Predecessor
1	*Project Start*	0	-
2	*Project Management & Service*	78	1FS+5
3	*Pipeline Report (Engineering)*	66	1FS+2
4	*Pipeline Drawing (Engineering)*	65	1FS+2; 3SS
5	*Material Take off (Engineering)*	45	1FS+2; 3SS
6	*Request for Quotation (Engineering)*	37	1FS+3; 3SS+1
	------------------ ------------------ ------------------		
32	*Post-Lay Survey (Installation)*	5	26FS
33	*Pre-Commissioning Pipeline A*	6	0FS; 31FS; 32FS
34	*Pre-Commissioning Pipeline C*	9	33FS
35	*Pre-Commissioning Pipeline B*	9	34SS
36	*Provisional Acceptance (PAC)*	0	35SS
37	*Punch List PAC Completion*	18	33FS
38	*Final Acceptance*	12	36FS; 37FS+20

4.2 Creating a Gantt Chart using Primavera P6 to Obtain a Network Diagram

Primavera P6 outputs are in the form of Gantt charts and network diagrams. The network diagram formed in Primavera P6 is a diagram of type AON (Activity on Node) where project activities are represented in nodes. However, Primavera P6 is not able to show the number of ES (Initial Start), EF (Initial Finish), LS (Delayst Start), and LF (Delayst Finish) manually.

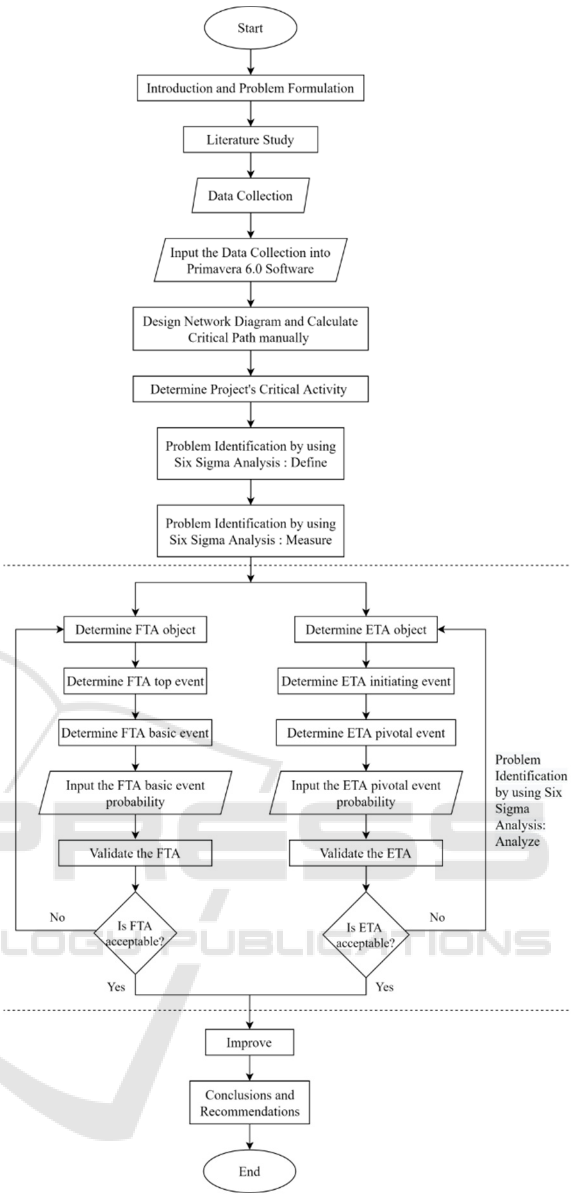

Figure 1: Flowchart.

4.3 Make Network Diagrams and Perform Critical Path Method Calculations Manually

This critical activity forms a critical path where if one or more project activities are delayed, it will cause the entire project to be delayed. Therefore, activities in the critical path need more supervision in the timeliness of completion. The activity nodes coloured in red indicate the critical activities and the direction of the red arrows indicate the critical paths.

4.4 Problem Identification using Six Sigma Analysis (Define)

At this stage a project charter will be made to revew information and problems that will occur in the offshore pipeline replacement project of the company under study. Project charter can provide information about general information, project scope, resource requirements, critical time schedules, roles and responsibilities of the project team.

Table 3: Project Charter - Project Scope.

Project Scope
Situation / Problem / Opportunity
In this project there are indications of delays due to a large deviation in the project planning data.
Project Goals
Maintaining the company's oil and gas production as well as to obtain additional production by installing a new pipeline to replace the existing damaged pipe.

Table 4: Project Charter - Project Scope.

In Scope / Out of Scope
In Scope: ● Installation of new pipes with a 12 "OD size and 1 km pipe length. ● Pre construction survey. ● Removal of the subsea obstacle that can hinder the installation of new pipes. ● Survey of laying subsea pipelines with ROV. ● Installing risers, bends, and spools. ● Post lay survey. ● Installation supports on pipelines identified as free spans. ● Flooding, pigging, hydrotest, drying, purging and pre-commissioning of new pipes. ● Installation of break out spool between riser and topside piping. ● Disassemble existing OD 8 "riser sizes, including riser clamps and end caps installation. ● Carry out work activities using a pressurized environment for installing riser clamps. ● Perform bevel end repairs at the end of the pipe. ● Welding procedure specifications using ASME IX code, API 1104 (PSL 2), AWS D1.1 and company specifications.
Out of Scope: ● There are no monetary problems at home or abroad during the project work. ● Project detail procedure has not changed and is in accordance with the contract during the project work.

Table 5: Project Charter - Project Scope.

Objectives
● Project on schedule. ● Without problems or work accidents. ● The project does not over cost. ● Stages of work are carried out according to quality standards.
Project Assumptions
● The document engineering process ran smoothly. ● The procurement process went smoothly. ● The construction process is running smoothly. ● The installation and checking process runs smoothly.
Risk and Dependencies
● Lack of resources. ● The risk of a project being delayed due to concurrent workers.
Risk and Dependencies
● Increased project costs due to accuracy of cost estimates and poor scope. ● Risk that the project will fail to produce results according to project specifications. ● Mistakes in strategies such as choosing technology that cannot function properly. ● Operational risks include risks from poor implementation and process problems such as procurement, production and distribution. ● Risks associated with external hazards, including storms, floods and earthquakes.

4.5 Problem Identification using Six Sigma Analysis (Measure)

In calculating and identifying the problem, timeliness is defined as an element which directly redelayd to the expected time calculation. Project planning time must be according to actual progress time. Therefore, at this stage an analysis is carried out to determine the sigma value with a percentage deviation between the time of planning and the time of progress with the maximum value of 6. The sigma value is obtained from the conversion of DPMO (defects per million opportunities) value. The DMPO value is derived from the difference of project time (in percentage), i.e. the deviation that occurs between the time of project planning and the time of actual progress.

For detailed calculation, the biggest deviation between monthly planning time and the actual time is taken. The result found that in October there was a time lapse of 5.05%. Defective Value per Million Opportunities (DPMO) is obtained from the formula:

$$\boxed{\text{DPMO} = \text{Large Deviation} \times 1000000}$$

In this calculation, the DPMO value is:
DPMO = 5.05% × 1000000 = 50500

DPMO calculation results show any deviations from the target that was decided. This DPMO number will then be used to get the sigma level by converting the DPMO number to the sigma number.

In the calculation of more specific sigma numbers, calculations can be performed using Microsoft Excel. The formula for calculating sigma number is:

$$\boxed{\text{Sigma Number} = \text{NORMSINV } (1 - \text{Large Deviation} + 1.5}$$

By using pre-existing data, the sigma number is as follows:

Sigma Number = NORMSINV (1 - 5.05%) +1.5 = 3.140025

The sigma calculation results show a more specific result of 3.14 out of 6 (maximum) which can be increased again with improvements made. This result occurred in October where there were 3 procurement, construction and installation.

Table 6: The Basic Event and Intermediate Event of the FTA Procurement Phase Experienced Interference.

Intermediate Event Level 1	**Intermediate Event Level 2**	**Basic Event**
Procurement Stage Experiencing Interference	Problem in ordering material	Planning is not mature enough procurement
		Material provider negligence
		Communication and coordination are unclear
	Material arrived at the project site delay	Shipping goods from abroad
		Material order delay
		The fabrication process has been delayed
		Material delivery is delay
	Problems with payment	

Table 7: Basic Event and Intermediate Event FTA Construction Phase Experienced Disruption.

Intermediate Event Level 1	**Intermediate Event Level 2**	**Basic Event**
Construction Phase Has Disturbances	Problematic equipment section	Lack of equipment
		The equipment is damaged
		Equipment arrived delay
		Low ability of equipment
	The labor force has a problem	Lack of workforce
		Difficulties in labor mobilization
		Labor productivity is lacking
		Absent laborers
		Inexperienced workforce
		Problems arise between workers
	Design changes that resulted in the addition of work	
	Bad weather	
	Natural Disaster	
	An accident occurred during the construction process	Unexpected accident
		Lack of supervisor and control
		Communication and coordinator are unclear
		Problems arise between workers
		Lack of socialization and work safety training
	An error occurred during the construction process	Document/ picture not detail
		Inexperienced workforce
		Communication and coordination are unclear

4.6 Identifying Problems and Calculating Probability of Problems using Six Sigma Analysis (Analyze): Fault Tree Analysis and Event Tree Analysis

- Determine top FTA events and ETA initiating events:

The top event and initiating event that is being investigated is the delay in the offshore pipeline replacement project.

Table 8: The Basic Event and Intermediate Event of the FTA Installation Stage Are Interrupted.

Intermediate Event Level 1	Intermediate Event Level 2	Basic Event
Installation Phase Has Interference	Problem in equipment section	The equipment is damaged
		Low standard of equipment
	Bad weather	
	Natural disaster	
	An accident occurred during the installation process	Unexpected accident
		Lack of supervision and control
		Communication and coordination are unclear
		Problems arise between workers
		Lack of socialization and work safety training
	An error occurred during the installation process	Document/ picture not detail
		Inexperienced workforce
		Communication and coordination are unclear

Table 9: Top Event Probability.

No	Basic Event	Probability
1	Procurement Stage Experiencing Interference	0,008360286
2	Construction Phase Has Disturbances	0,022554886
3	Installation Phase Has Interference	0,021781371
Top Event Probability (Total)		0,052696543

- Determine basic FTA events and ETA pivotal events:

Basic events and pivotal events are determined by conducting a literature review of delays in construction projects and subsea pipeline projects. The results of the basic event and pivotal event are obtained after validating to the respondent (client side).

Opportunities for each basic event were obtained with a questionnaire from 7 respondents experienced in underwater piping projects. After that, do the calculations to get the probability of intermediate events and top event. The event tree diagram shows that the initiating event of this research is that the delay offshore pipelines replacement project has 6 probability events A, B, C, D, E, and F.

(a) Event A
Replacement of the underwater pipeline is completed on time because it runs smoothly and there is no problem in one of the pivotal events. The probability of Event A is 0.05270 x 0.83 x 0.77 x 0.80 x 0.69 x 0.71 = 0.0132

(b) Event B
Replacement of underwater pipelines is complete but can be delayed for 5-6 weeks due to shortages and conditions of available equipment. The probability of Event B is 0.05270 x 0.83 x 0.77 x 0.80 x 0.69 x 0.29 = 0.0053

(c) Event C
Replacement of underwater pipelines is complete but can be delayed for 3-4 months due to lack of manpower and inexperience. The probability of Event C is 0.05270 x 0.83 x 0.77 x 0.80 x 0.31 = 0.0085.

(d) Event D
Replacement of underwater pipelines is complete but can be delayed for 4-5 months due to delays in procurement. The probability of Event D is 0.05270 x 0.83 x 0.77 x 0.20 = 0.0067

(e) Event E
Replacement of subsea pipelines is complete but can be delayed for 5-6 months due to lack of implementation and supervision of project management. The probability of Event E is 0.05270 x 0.83 x 0.23 = 0.0100

(f) Event F
Replacement of subsea pipelines cannot be resolved due to cost issues during the project, considering costs are the main thing of the project's success. The probability of Event F is 0.05270 x 0.17 = 0.0090

The next step is to determine the risk categories of each event into the risk matrix. The probabilities of each output are matched into the Frequency Index (FI) table and the consequences of each output are matched into the Severity Index (SI) table. The FI and SI tables are referenced from DNV RP F107 (Pipeline Risk Assessment).

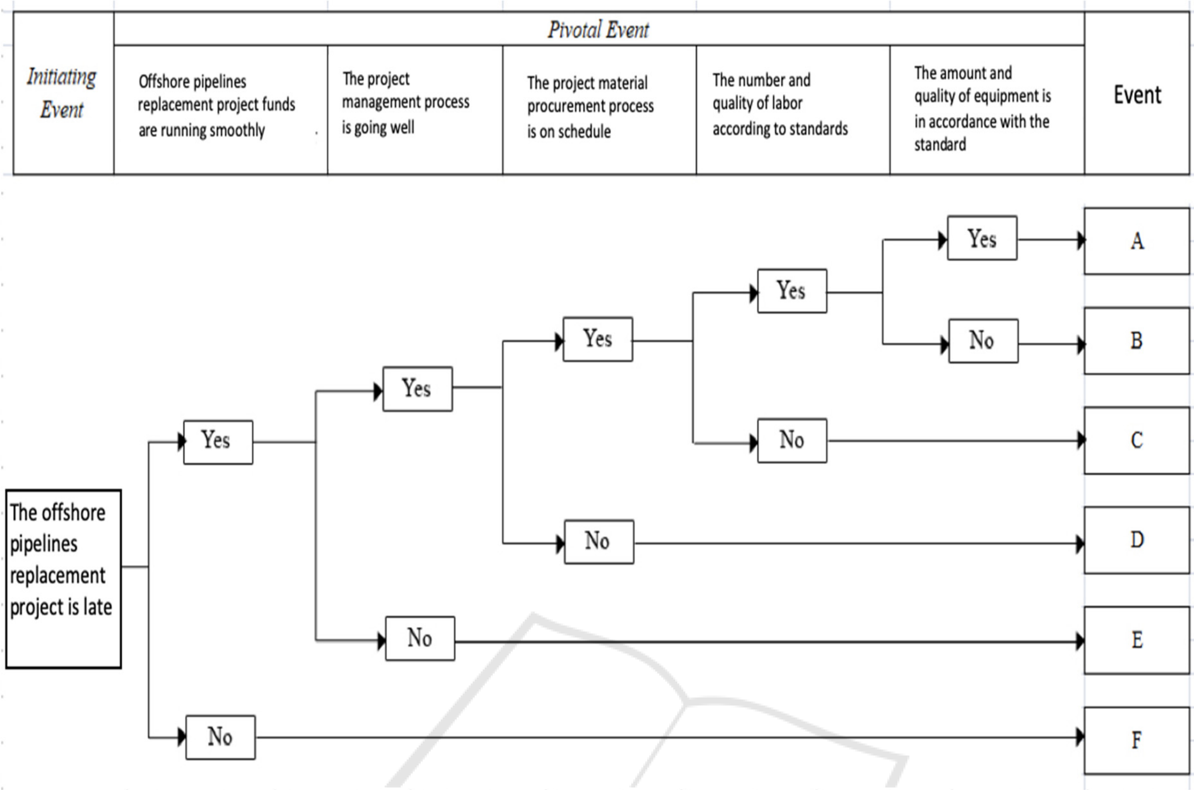

Figure 2: Event Tree Diagram.

Table 10 explains that event A is categorized as moderate risk while events B, C, D, E, and F are categorized as high risk due to high probability and high severity. In this result, there is no low risk result because the lowest probability of event is categorized as high probability (4) and very high (5).

Table 10: Risk Matrix.

		Severity				
		1	2	3	4	5
Frequency	5	A			E	F
	4			B	C, D	
	3					
	2					
	1					

High Risk Medium Risk Low Risk

4.7 Determination of Problems using Six Sigma Analysis (Improve)

It is known that in that month there are material delivery activities, the likelihood of this happening is that the material delivery is delayed in view of the large probability at the basic event. Delay material delivery has a probability of 0.007389714.

The step that can be taken is to complete all material financing because monitoring of funding in ordering materials is important because in the absence of funds the goods cannot be ordered or delivered on time. For the next project, it is expected that the procurement plan can be planned as well as possible so that there are no more errors in the delivery of materials and the project is running optimally.

5 CONCLUSIONS

Based on discussion in the previous chapter, these are the conclusion of the study:

1. The offshore pipelines replacement project has 19 critical activities created from 38 project

activities.

2. Many factors cause project delay. These factors are divided into 3 intermediate event branches, namely the procurement, construction and installation stages.
3. The offshore pipelines replacement project using Fault Tree Analysis (FTA) obtained the results of the top event probability on this project of 0.05270.
4. Offshore pipelines replacement project using Event Tree Analysis (ETA) obtained 6 events with different probabilities and consequences.

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