Risk Analysis on Offshore Pipeline Installation Delay: A Case Study for Mahakam Block, Indonesia

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Abstract: Pipeline has an important role in oil and gas industry to transfer oil or gas that have been discovered to production station, one of which is pipeline system belong to one of the companies located in Mahakam Block, East Borneo, Indonesia. Considering its important role, pipeline installation in not allowed for any delay and needs to operate as planned. However, the said offshore pipeline installation has experienced 21 days of delay, whereby this project started on December 5th 2018 and finished at February 3rd 2019. To analyse the delay of this project, this research uses two methods, namely fuzzy trapezoidal and bowtie analysis. The fuzzy fault tree analysis (FTA) diagram will generate the probability value of top event project delay of offshore pipeline installation. The fuzzy event tree analysis (ETA) diagram will generate how much fine that the contractor has to pay and the risk level from every factor that causes the delay. The results from bowtie analysis will determine preventive value which will be used as precaution and mitigation which will be used as reduction due to delays.

1 INTRODUCTION

In this modern era, oil and gas demands continue to rise, to meet consumer demands oil and gas companies have to increase their production performance. In this industry, pipeline has an important role to transfer crude oil that has been discovered from well to production station.

This research discuss the project of offshore pipeline installation belongs to one of the oil and gas company in Mahakam. This pipeline located in Mahakam Block, East Borneo, Indonesia. This pipeline is connecting two wells at a distance of 0.8km.which the installation shall be commenced from 5th December 2018 to 13th January 2019. during the execution, this project delayed for 21 days causing the project to be completed on 3rd February 2019 instead.

Delays on projects can cause losses to both the owner and the contractor. From ownerpoint of view, the construction delay eventually will impact on the progress of the production, in a way affecting the profit. From contractor point of view, extra cost will incurred e.g. on equipment rent and fines (Muhamad, 2016).

To reduce the possibility of delays on offshore pipeline installation in the future, risk analysis can be used.Project delay for jacket structure and HRSG have been reviewed by (Silvianita et al 2017a, 2017b) and another project delay using Fault Tree Analysis (Silvianita et al 2014). This paper will examine the most dominant factor causing the delay on offshore pipeline installation project at the company. Pipeline specification data can be seen in Table 1.

Table 1: Pipeline Specification Data.

Description	Specification
Pipe Material	API 5L X 65
Outside Diameter	8.625 in
Line Pipe	12 m
Pipeline Wall Thickness	20.6 mm
Pipe Length	800m

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2 LITERATURE STUDIES

Fault tree analysis (FTA) is a logic and graphical representation that explores the interrelationships between a potential critical events in a system and the reason for event (Mokhtari et al, 2011). FTA diagram consists of top event and basic events. Commonly, FTA method is used to find the probability of top event.

Meanwhile, Event tree analysis (ETA) is a method to detect and analyze the different events of pragmatic accidents possibilities with safety features following an initiating event (Raiyan et al, 2017). ETA diagram consists of initiating event and pivotal events, which normally used to analyzeconsequence that arise from failure or unwanted event.

To covers the loss event scenario uses a Bowtie diagram that consists of fault tree (FT) and Event Tree (ET) to identify the causes of top events or loss events and shows the consequences of unwanted events.The weakness of bowtie analysis is that the opinions used in the analysis have uncertainties and vaguenesses.

FTA and ETA considered probability value to determine cost of delaying fortop event of FTA and initiating event of ETA respectively. But in the execusion, these methods will produce unrealistic outcome as the probability values are solely depend on assumptions and lead to erroneous conclusion.

Fuzzy logic was introduced to overcome the ambiguity of human judgement as it can change the probability value to possibility number within the scale of 0-1. According to Aqlan et al (2014), fuzzy logic is used to find aggregates or the value of the word variable (linguistics) of the respondent, which are converted into a collection of numbers. The scale used in fuzzy logic is more flexible, making it easier to assess linguistic variables according to condition in the field (Shahriar, 2012). In this research, the use of linguistic variables and fuzzy numbers are as follow (Zarei et al, 2019).

Table 2: Fuzzy Likelihood of an Event (Zarei et al, 2019).

Grade	Likelihood	Membership Function
1	Very High (VH)	(0.8,1,1,1)
2	High-Very High (HVH)	(0.7,0.9,1,1)
3	High (H)	(0.6,0.8,0.8,1)
4	Fairly High (FH)	(0.5,0.65,0.65,0.8)
5	Medium (M)	(0.3,0.5,0.5,0.7)
6	Fairly Low (FL)	(0.2,0.35,0.35,0.5)
7	Low (L)	(0,0.2,0.2,0.4)
8	Low-Very Low (LVL)	(0,0,0.1,0.3)
9	Very Low (VL)	(0,0,0,0.2)

This research using the trapezoidal fuzzy number to determine the possibility value from respondents assumptions based on interview. Trapezoidal fuzzy number can be defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, \; x < a_1 \\ \frac{x - a_1}{a_2 - a_1}, \; a_1 \leq x \leq a_2 \\ 1, \; a_2 \leq x \leq a_3 \\ \frac{a_4 - x}{a_4 - a_3}, \; a_3 \leq x \leq a_4 \\ 0, \; x > a_4 \end{cases} \quad (1)$$

The formula can be defined as follows :

$$X^* = \frac{\int_{a_1}^{a_2} \frac{x-a_1}{x-a_2}\, xdx + \int_{a_2}^{a_3} xdx + \int_{a_3}^{a_4} \frac{a_4-x}{a_4-a_3} xdx}{\int_{a_1}^{a_2} \frac{x-a_1}{a_2-a_1} dx + \int_{a_2}^{a_3} dx + \int_{a_3}^{a_4} \frac{a_4-x}{a_4-a_3}\, dx}$$

$$X^* = \frac{1}{3} \times \frac{(a_4 + a_3)^2 - a_4 a_3 - (a_1 + a_2)^2 + a_1 a_2}{(a_4 + a_3 - a_1 - a_2)} \quad (2)$$

According to Clemen et al (1999) to change the linguistic variable to fuzzy number and combine the value of experts assumption to one fuzzy number, the formula can be defined as follows:

$$M_i = \sum_{i=1}^{m} W_j A_{ij}\; , j = 1,2, \ldots, n \quad (3)$$

Where :

Aij = Linguistic expression of basic event by j

M = Number of basic events

n = Number of experts

W = Weighting factor of j and M

Representing the combined Fuzzy number of basic event i.

According to Lavasani et al (2012) the value of experts assumption can be determined by this following formula :

$$\text{Experts value} = PP + ET + EL + A \quad (4)$$

$$\text{Wj} = \frac{\text{value of expert}}{\sum_{i=1}^{n} \text{value of expert}} \quad (5)$$

Where:

PP = Professional Position

ET = Education Level

EL = Experience Time (year)

A = Age (year)

Wj = weighting factor of experts

Table 3 shows the value of experts (Ramzali et al, 2015).

Table 3: Value for Experts.

Constitution	Classification	Score	Constitution	Classification	Score
Professional Position	Senior academic	5	Education Level	PhD	5
	Junior academic	4		Master	4
	Engineer	3		Bachelor	3
	Technician	2		Higher National Diploma (HND)	2
	Worker	1		School Level	1
Experience Time (year)	≥30	5	Age (year)	≥50	4
	20-29	4		40-49	3
	10-19	3		30-39	2
	6-9	2		<30	1
	≤5	1			

According to Onisawa (1998) to change the fuzzy possibility score (FPs) by summing the three fuzzy number parameters and the dividing by three. For the last step, change the FPS to fuzzy probability score (FPr) using the following formula:

$$FPr = \begin{cases} \frac{1}{10^k} & \text{if } FPs \neq 0 \\ 0 & \text{if } FPs = 0 \end{cases} \quad K = \left[\left(\frac{1-FPs}{FPs}\right)\right]^{\frac{1}{3}} \times 2.301 \qquad (6)$$

Where :

FPr = Fuzzy Probability Score

FPs = Fuzzy Posibilatas Score

K = Constant Numbers

The probability will be used to calculate the possibility on ETA fuzzy diagrams. To change the probability to possibility by using the following formula (Onisawa, 1988):

$$FPs = f(FPr)$$

$$FPs = \begin{cases} \frac{1}{\left(1+\left(k\times\log\left(\frac{1}{Fpr}\right)\right)^3\right)}, & FPr \neq 0 \\ 0, & FPr = 0 \end{cases} \qquad (7)$$

Where :

FPr = Fuzzy Probability Score

FPs = Fuzzy Posibilatas Score

$$k = \frac{1}{Log\,(1/(5\times10^{-3}))}$$

3 METHODOLOGY

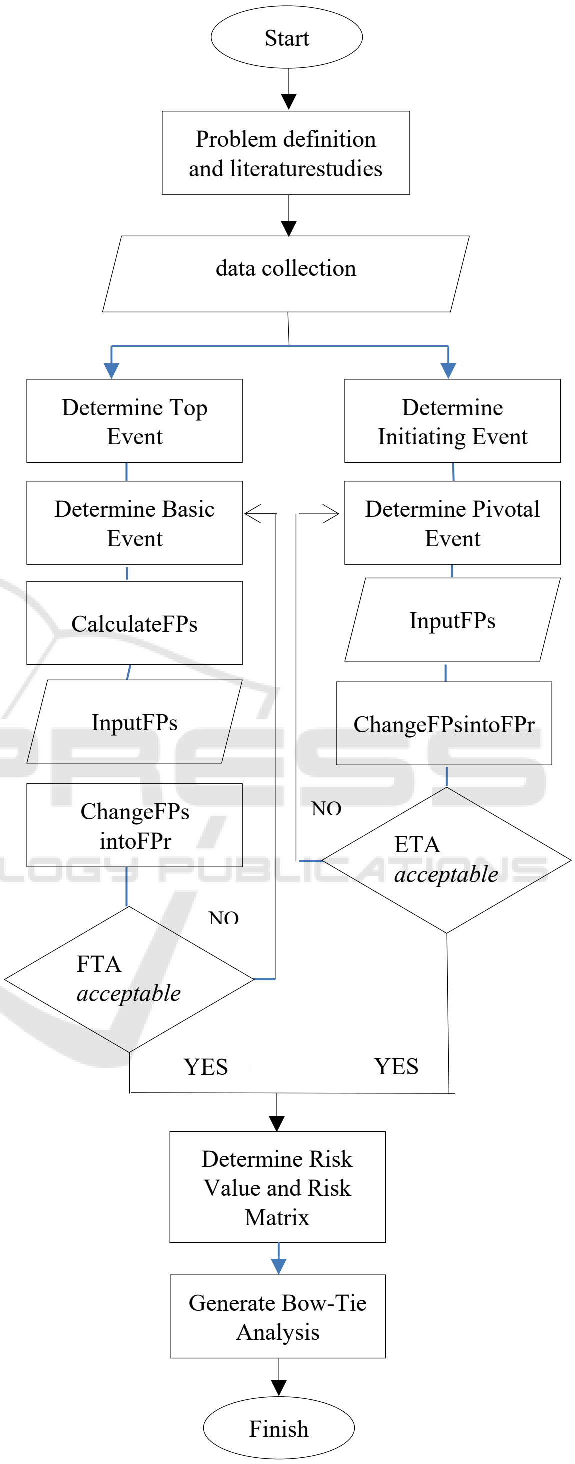

Figure 1: Flowchart.

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

3. Data Collection
   The data used in this research are:
   a. Pipeline installation project master schedule data
   b. Actual pipeline installation project data schedule
   c. Contract data
   d. General data about the pipeline installation project
   e. Make a questionnaire to look for the probability
      of basic FTA events, pivotal ETA events, determination of risk matrices, barriers and escalation factors in a bow-tie diagram.

4. Data Analysis and Discussion
   a. Analysis of the results of the interview to determine the work items that are experiencing problems, thefactors that cause delays in the project and theconsequences caused by delays. At this stage a weighting is carried out for each respondent withequations 4 and 5
   b. Fuzzy FTA stage
   c. Fuzzy ETA stage
   d. Determine the Risk Matrix
   e. Bowtie Analysis

5. Conclusions and Suggestions
   After all the results are obtained, conclusions are then drawn up containing the answers to the formulation of the existing problems and suggestions for further research, especially in the field of Risk Assessment.

4 RESULT AND DISCUSSION

4.1 Data Management Factors Delaying Offshore Pipeline Installation using Fault Tree Analysis and Fuzzy Logic

Fault tree analysis (FTA) is a method used to find therootcauses of a top event or peak failure event.Thisresearch explained the factors that cause the delay in the offshore pipeline installation project. The basic causes of delays and the probability of each basic event were illustrated through a fault tree diagram. The basic events can be seen in Table 4.

Table 4: Basic Event of FTA Diagram.

No.	Code	Name of Event
1	A111	Equipment / machinery not available
2	A112	Equipment / machinery is being used in another location
3	A121	Poor equipment / machinery maintenance
		.....
25	B11	Miscommunication between owner supervisor and contractor
26	B12	Workers do not understand the work items to do
27	B2	The process is not according to the initial plan

Meanwhile, the respondent's personal data can be seen in Table 5, and the respondents involved in the offshore pipeline installation were selected:

Table 5: Respondent Profile.

Expert	Category			
	Age	Experiences	Postion	Education
1	34	12	Site Planner	S2
2	29	11	Engineer	S1
3	40	17	Supervior	S1
4	26	5	Engineer	S1
5	29	6	Engineer	S1
6	32	8	Site Manager	S1
7	26	5	Engineer	S1
8	39	12	Supervisor	S2
9	28	5	Engineer	S1

Probability of each basic FTA was obtained throughinterviewing the respondents. the frequency of basic fuzzy FTA events was referred to the scale proposed by Zarei, et al. (2019), as listed in Table 6.

Table 6: Scale Fuzzy Likelihood of an Event.

Linguistic Variabel	Defenition	Membership Function
Very High (VH)	It happened every pipeline installation	(0.8,1,1,1)
High-Very High (HVH)	It happened in a span of 3 times the pipeline installation	(0.7,0.9,1,1)
High (H)	It happened in a span of 5 times the pipeline installation	(0.6,0.8,0.8,1)
Fairly High (FH)	It happened in a span of 15 times the pipeline installation	(0.5,0.65,0.65,0.8)
Medium (M)	It happened in a span of 25 times the pipeline installation	(0.3,0.5,0.5,0.7)
Fairly Low (FL)	It happened in a span of 50 times the pipeline installation	(0.2,0.35,0.35,0.5)
Low (L)	It happened in a span of 75 times the pipeline installation	(0,0.2,0.2,0.4)
Low-Very Low (LVL)	It happened in a span of 90 times the pipeline installation	(0,0,0.1,0.3)
Very Low (VL)	It happened in a span of 100 times the pipeline installation	(0,0,0,0.2)

4.1.1 Calculating Fuzzy Possibility (FPs)

From the results of interviews and questionnaires, a recapitulation of data for linguistic variable scales were compiled in Table 7.

Table 7: Questionnaire Results from Experts.

Activity	Category								
	1	2	3	4	5	6	7	8	9
A111	VL	VL	H	LVL	LVL	VL	L	M	L
A112	L	VL	HVH	L	FL	M	L	M	M
A121	L	LVL	VH	LVL	FL	L	LVL	M	LVL
.....									
B11	LVL	LVL	FL	LVL	M	VL	LVL	H	FL
B12	LVL	FH	FL	VL	L	L	VL	M	LVL
B2	LVL	FH	L	M	M	L	VL	M	FL

To determine the possibility of each basic event, the first step to identify the weight for each respondent adopting equations 4 and 5, while the scores for respondents based on Table 3.
The example of value calculating of aexpert:

Value of expert = PP + ET + EL + A
= 3 + 3 + 4 + 2
=12

$$Wj = \frac{weight\ of\ experts}{\sum_{i=1}^{n} weight\ of\ experts}$$

$$Wj = \frac{12}{12+10+12+8+10+11+8+12+8}$$

$$Wj = \frac{12}{91}$$

Wj = 0,13

From the calculations above, we get the value of each respondentas written in Table 8.

Table 8: Value of Each Experts.

Respondent	Final Score
1	0.13
2	0.11
3	0.13
4	0.09
5	0.11
6	0.12
7	0.09
8	0.13
9	0.09

After knowing the weight of each respondent, then determined possibilities (FPs) of each basic event using equation 2 and 3.

We used Basic Event code A111 from the questionnaire results as an example to calculate the possibility (FPS).

Table 9: Questionnaire Results A111.

Experts								
1	2	3	4	5	6	7	8	9
VL	VL	H	LVL	LVL	VL	L	M	L

Table 9 shows the outcome of questionnaire survey. Then fuzzy numbers as in table 6 were converted to calculate the possibility (FPs). The results can be seen as below:

Expert 1 = (0, 0, 0, 0.2)
Expert 2 = (0, 0, 0, 0.2)
Expert 3 = (0.6, 0.8, 0.8, 1)
Expert 4 = (0, 0, 0.1, 0.3)
Expert 5 = (0, 0, 0.1, 0.3)
Expert 6 = (0,0, 0, 0.2)
Expert 7 = (0, 0.2, 0.2, 0.4)
Expert 8 = (0.3, 0.5, 0.5, 0.7)
Expert 9 = (0, 0.2, 0.2, 0.4)

using equation 3, by multiplying the following fuzzy number with the weight of each respondent defined in Table 8.The following results were derived:

Expert 1 = (0, 0, 0, 0.2) x 0.13
= (0, 0, 0, 0.026)
Expert 2 = (0, 0, 0, 0.2) x 0.11
= (0, 0, 0, 0.022)
Expert 3 = (0.6, 0.8, 0.8, 1) x 0.13
= (0.078, 0.104, 0.104, 0.13)
Expert 4 = (0, 0, 0.1, 0.3) x 0.09
= (0, 0, 0.009, 0.027)
Expert 5 = (0, 0, 0.1, 0.3) x 0.11
= (0, 0, 0.011, 0.033)
Expert 6 = (0,0, 0, 0.2) x 0.12
= (0, 0, 0, 0.024)
Expert 7 = (0, 0.2, 0.2, 0.4) x 0.09
= (0, 0.018, 0.018, 0.036)
Expert 8 = (0.3, 0.5, 0.5, 0.7) x 0.13
= (0.039, 0.065, 0.065, 0.091)
Expert 9 = (0, 0.2, 0.2, 0.4) x 0.09
= (0, 0.018, 0.018, 0.036)

The fuzzy numbers isthen summed, to obtain the ultimate fuzzy number, as follows:

M = R1 + R2 + R3 + R4 + R5 + R6 + R7 + R8 + R9
= (0 + 0+ 0.078 + 0 + 0 + 0 + 0 + 0.039 + 0 ; 0 + 0 + 0.104 + 0 + 0 + 0 + 0.018 + 0.065 + 0.018 ; 0 + 0 + 0.104 + 0.009 + 0.011 + 0 + 0.018+ 0.065 + 0.018 ; 0.026 + 0.022 + 0.130 + 0.027 + 0.033 + 0.024 +0.036 + 0.091 + 0.036)
= (0.12 ; 0.21 ; 0.23 ; 0.43)

Considering Eq (2), the Fuzzy Probability Score for event A111 can beobtained as follows:

$$FPs = \frac{1}{3} \times \frac{(0.43+0.23)^2-(0.43\times0.23)-(0.12+0.21)^2+(0.12\times0.21)}{(0.43+0.21-0.12-0.21)}$$
$$= \frac{1}{3} \times \frac{0.25}{0.33}$$
$$= 0.25$$

Similar procedure was repeated for the rest of the events and the results are as shown in Table 10.

Table 10: Calculation Results of Fuzzy Possibility (FPs).

No	Code	Fuzzy Number				FPs
		a	b	c	d	
1	A111	0.12	0.21	0.23	0.43	0.25
2	A112	0.22	0.39	0.40	0.57	0.39
3	A121	0.17	0.29	0.32	0.49	0.32
....	...	....	....	....	....	....
25	B11	0.16	0.24	0.28	0.47	0.29
26	B12	0.12	0.23	0.25	0.44	0.27
27	B2	0.17	0.32	0.33	0.52	0.34

After finding the FPs of each basic event from the Fuzzy FTA Diagram, were thenconverted the possibility (FPs) to probability (FPr) using equation 6. The results of FPr are shown in Table 11.

Table 11: Calculation Results of Fuzzy Probability (FPr).

No.	Code	FPs	K	FPr
1	A111	0.25	3.30	0.0005
2	A112	0.39	2.66	0.0022
3	A121	0.32	2.,95	0.0011
....	...	....	....	....
25	B11	0.29	3.09	0.0008
26	B12	027	3.23	0.0006
27	B2	0.,34	2.88	0.0013

The next step is calculating the minimum cut set by input the Fuzzy probability from each basic event to Top Event FTA software.

Calculations using the software will produce the Top Event Probability and Intermediate Event Probability values shown in Figure2.

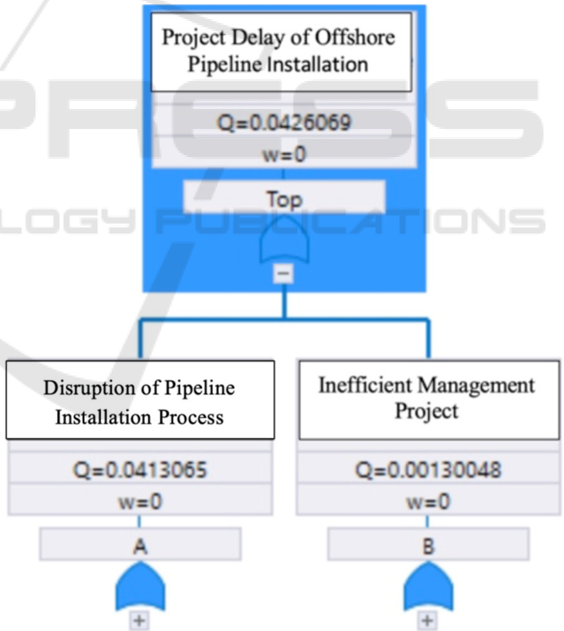

Figure 2: Minimum cut set results from Fuzzy FTA.

Figure 2 showed the minimum cut sets of fuzzy fault tree analysis (FFTA). The minimum cut set for project delay of offshore pipeline installation are due to disruption of pipeline installation process with a probability 0.04135065 and inefficient management project has a probability of 0.00130048. So the minimum total cut set for the top event is 0.0426069.

5 CONCLUSION

Based on discussion in the previous chapter, it can be conclude that the most dominant factor causing delays in offshore pipeline installation projects is Disruption of Pipeline Installation Process with a probability of 0.0413 and Inefficient Management Projectwith a probability of 0.0013.

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