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Project Delay Factor Analysis Using Fault Tree Analysis (FTA) Method and Rescheduling with Critical Path Method (CPM) in Ducting Manufacturing Projects at PT. FRA

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Abstract. Ducting manufacturing project at PT. The FRA was planned to be completed in 14 days, but was implemented in 19 days and 5 days late. The method to find the cause of project delays is Fault Tree Analysis (FTA), then analyze rescheduling with the Critical Path Method (CPM). The purpose of this study is to identify factors of work delay, determine new steps for project contractors and reschedule with alternative working hours and labor additions. The results of the analysis using the FTA method obtained the main cause of delay in drawing engineering work of 0.0002592 and obtained 4 new steps for project contractors. The results of rescheduling using the CPM method obtained a percentage increase in productivity with the alternative of adding working for 4 hours with a duration of 25% or 6 days faster than the normal duration of 19 days to 13 days and an additional cost of 91.96%, which is Rp. 21,500,000. While the percentage of productivity increase with alternative labor additions with a duration of 38.75% or 5 days faster than the normal duration of 19 days to 14 days and additional costs of 178.57%, namely Rp. 31,200,000. So it can be concluded by using the FTA method the main cause is drawing engineering work and 4 new steps are obtained and using the CPM method alternative scheduling is obtained to increase overtime work hours more effectively and additional costs are not too large, so that the company does not experience delays for future ducting projects.
Keywords: Project delay, Fault Tree Analysis, Critical Path Method, Reschedule.

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1. Introduction

Project delays occur if the contractor does not complete the project according to the time schedule agreed in the contract, then the delay has the impact of increasing project costs, increasing market risk, increasing production delay time and project delays[1]. Project management aims to execute projects well to minimize problems during project implementation, so an accurate project management system is needed for effective and efficient scheduling[2]. PT. FRA is a project based steel fabrication manufacturing and service company that aims to improve the effectiveness and efficiency of the production process[3]. The company is engaged in steel manufacturing, heavy equipment operation and maintenance[4]. Each project has a different design and function to process raw materials that are assembled to be formed to produce new materials to have added functions and value. Problems of PT. FRA is a delay ducting line 149-152 project that the project owner of PT. MBI. Every project has a

planned schedule, but schedules and deliverables in the field show different project completion times. The ducting project was planned to be completed in 14 days, but it was carried out in 19 days and 5 days late. Because there are many delay factors in the project, it is necessary to analyze the Fault Tree Analysis (FTA) method to analyze the factors causing delays and the Critical Path Method (CPM) method to get rescheduling with alternative work hours and alternative labor additions.

Fault Tree Analysis (FTA) is an analysis method by displaying drawings and evaluating paths in a system to minimize costs[5]. Fault Tree Analysis is used to identify the root of the fault tree[6]. FTAs are also used to identify the causes of failures in visual diagrams and logic models[7]. Critical Path Method (CPM) is a project management method with a focus on the timing of work activities and defined critical path project duration[8]. The Critical Path Method details each activity, job activity, normal time and cost data for the network[9]. Based on the description above, researchers are interested in conducting research, the advantages of both methods are being able to find out the work and factors causing delays and determine new steps for project contractors and get rescheduling with alternatives to increase work hours and alternative labor additions in future projects.

2. Methods

The research methods in this study are qualitative and quantitative to obtain information about delays in projects, determine delay factors and make descriptive explanations about these factors can occur[10]. The subjects of this study analyzed the factors causing delays obtained from observations, interviews and questionnaire results distributed to respondents of planning production control (ppc) workers[11]. Fault Tree Analysis (FTA) method to process questionnaire data to determine the probability value to calculate the minimum cut set value. The ducting line 149-152 project at PT FRA is the object of research which contains time schedule data and reschedule data to obtain the schedule and project implementation presented in table 1 and table 2.

Table 1. Ducting Project Plan Schedule (Source PT. FRA)

NO	Job Description	Work Implementation Plan Schedule (Days)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
I	Engineering drawing work														
II	Material procurement work														
A	Cutting marking production work														
B	Machining production work														
C	Feedup production work														
D	Welding production work							Holiday							Holiday
E	Finishing work														
F	Quality control work														
G	Painting work														
H	Packing delivery work														

Table 2. Reschedule Ducting Project (Source PT. FRA)

NO	Job Description	Work Schedule (Days)																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
I	Engineering drawing work																			
II	Material procurement work																			
A	Cutting marking production work																			
B	Machining production work																			
C	Feedup production work							Holiday							Holiday					
D	Welding production work																			
E	Finishing work																			
F	Quality control work																			
G	Painting work																			
H	Packing delivery work																			

2.1 Data Collection

Data collection is used to obtain data by observation and interviews[12]. Data collection in this study there were 2 respondents, namely production supervisor workers who participated in the project directly in the field. Data collection from the interview process indudes ducting project data implemented by PT. FTA and its owner from PT. MBI was planned to be completed in 14 days, while the project implementation was postponed to 19 days and identifying the work that was the cause of the project delay was interviewed with one respondent, namely the supervisor of the production section of the ducting project.

2.2 Data Processing

Data processing is carried out to analyze project delay factors and reschedule projects which include late work factors, identifying engineering drawing work and material procurement work using the Faut Tree Analysis (FTA) method for a combination of events that cause root problems that affect the project[13]. After a combination of basic event calculation of mocus analysis and minimum cut set, then reschedule the duration of project activities, analyze the calculation of early start, early finish, latest start, latest finish of each job and identify the critical path network diagram, determine the shortest rescheduling of work duration with alternatives to increase work hours and increase manpower, after that determine the relationship between the results of the fault tree analysis analysis with the results critical path method and compares with new scheduling so that optimal project time is obtained.

3. Results and Discussion

3.1. Fault Tree Analysis (FTA)

Data management is carried out using the Fault Tree Analysis (FTA) method which obtained the following steps.

3.1.1 FTA Steps Steps (Fault Tree Analysis)

Fault Tree Analysis consists of a combination of sequential faults that cause a failure event[14]. The first step is defining events in the system, creating an error tree from top event to intermediate event and top event logic gate relationships. The next step is to calculate the minimum cut set and analyze the FTA using the probability values of intermediate events to top events. Here can be seen FTA diagram figure 1.

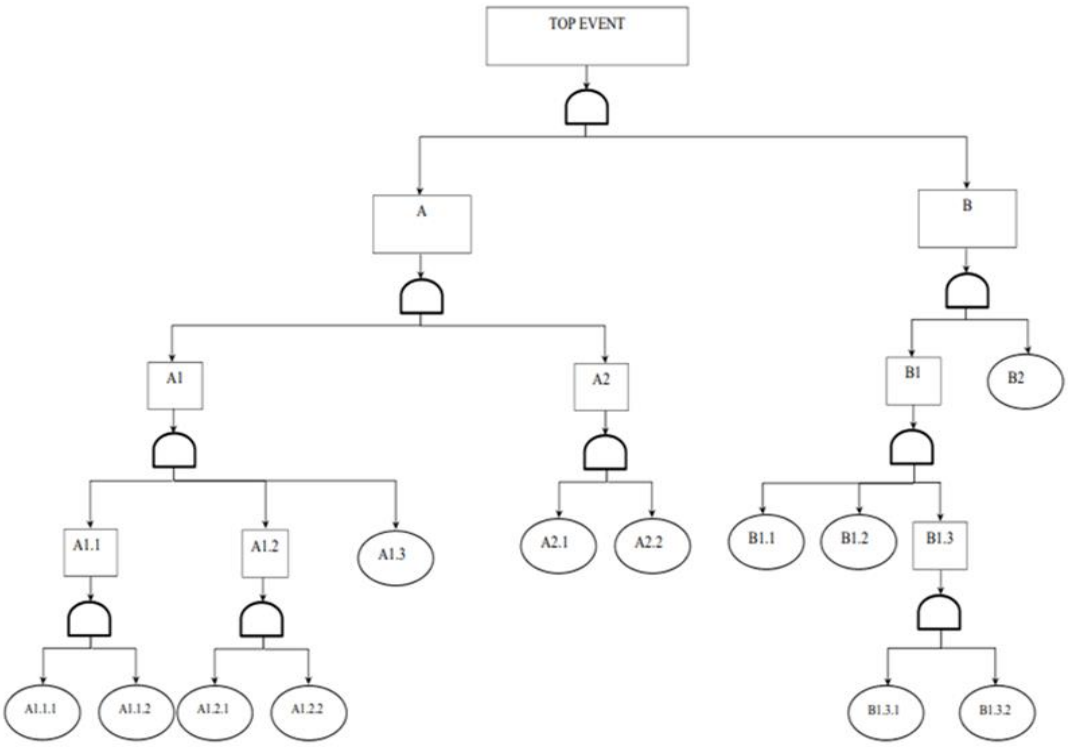

Figure 1. FTA Diagram Causes of Ducting Delays

3.1.2 Qualitative Analysis Fault Tree Analysis (FTA)

Analysis of the causes of delays in ducting projects at PT. FRA has two intermediate events from the interview results, namely drawing engineering work and material procurement work. In drawing engineering work, the problem is related to the owner's agreement, the main contractor and sub contractor cannot be agreed unilaterally when in the field, because they are still processing drawings with the owner's request to be reviewed again regarding their feedback. In material procurement work, it is still waiting for the owner's approval and drawing engineering work drawings, after the drawings come, the materials do not come immediately, because the company selects materials that propose prices in accordance with the project budget.

3.1.3 Quantitative Analysis Minimal Cut Set

Minimal cut set analysis is carried out with mocus analysis to find out the root of the problem in the fault tree[15]. Researchers distributed questionnaires to one respondent to find out the probability value and obtained 7 basic event mocus in drawing engineering work is A1.1.1; A1.1.2 ; A1.2.1 ; A1.2.2 ; A1.3 ; A2.1 ; A2.2 with a value of 0.4 x 0.4 x 0.3 x 0.3 x 0.3 x 0.3 x 0.2 = 0.0002592. In material procurement work, 5 basic events were obtained, namely B1.1; B1.2 ; B1.3.1; B1.3.2 ; B2 with a value of 0.4 x 0.3 x 0.3 x 0.4 x 0.4 = 0.00576. After conducting a Fault Tree Analysis (FTA) analysis, it is known that the event factors causing the delay in the ducting project and obtained 2 minimum cut sets, namely A = 0.0002592 and B = 0.00576 at PT. FRA can be seen in table 3.

Table 3. Event Fault Tree (Source PT. FRA)

Event	Information
A	Engineering drawing work
A1	Owner factor
A2	Maincont and subcont factors
A1.1	Slow owner in decision making
A1.2	lack of good coordination
A1.3	Owner's delay in reviewing feedback from maincont and subcont
A1.1.1	Waiting for the owner's decision regarding the drawing processing process

A1.1.2	Shop drawing release request
A1.2.1	Lack of coordination with maincont and subcont
A1.2.2	Late provision of drawing processing instructions
A2.1	Lack of coordination of subcont and maincont
A2.2	Re-drawing processing is carried out
B	Material procurement work
B1	Material selection factors
B2	Owner factor
B1.1	Propose a price according to the project budget
B1.2	Late PO fender list incoming material
B1.3	Delays in material delivery
B1.3.1	The materials ordered only came partially
B1.3.2	Not in accordance with the planned schedule

3.1.4 Analysis Sets a New Step

Researchers will determine a new step from table 3 event fault tree and a high probability value in engineering drawing work of 0,0002592 and material procurement work of 0,00576 to be combined which initially the factor causing the delay will be a new step factor, this way can optimize and will be usefull in the implementation of ducting projects in the company, then a new 4 steps will be obtained[16]. The first step is careful planning by creating a realistic project schedule with the project plan and identifying potential obstacle risks. The second step is to monitor project progress to track progress and changes to identify project delays early. The third step is effective communication between the company and the owner to provide periodic updates, monitoring work quality standards and the fourth step is planning schedule changes to anticipate if the planned project suddenly changes by communicating all parties in the project.

3.2. Critical Path Method (CPM)

The Critical Path Method can estimate the duration in the implementation of project activities that obtain supervision efficiently so that they are completed according to planning[17]. The critical trajectory of engineering drawing work activities with Early Finish (EF) = 2 days and Latest Finish (LF) = 4 days occurs slack 2 days. While EF material procurement work = 2 days and LF = 4 days there was a 2-day slack. Daily productivity calculation to compare production results with resources obtained value of volume of engineering drawing work = 4920.32 kg / 19 days = 258.964 kg / day.

3.2.1 Alternative Work Acceleration with Additional Working Hours (Overtime)

An alternative to speeding up project completion is the alternative approach of testing and implementing increasing overtime work hours[18]. Normal working hours on the project are 08.00-16.00 or 7 working hours and 1 hour rest at 12.00-13.00, additional ducting project working hours are 4 hours of work at 16.00-20.00. Calculation of additional productivity of drawing technique man-hours with daily productivity = 258.964 kg x 0.6 product reduction coefficient x 4 duration of overtime hours = 621.5136 kg. The calculation of the acceleration of adding working hours can be seen in table 4.

Table 4. Calculation of acceleration in addition to working hours

No	Job Description	Indeks (%)	Koef (-) Production	Overtime Hours	Prod. Planning
1	Engineering drawing work	258,964	0,6	4	621,5136
2	Material procurement work	170,328	0,6	4	408,7872
3	Cutting marking production work	134,901	0,6	4	323,7624
4	Machining production work	118,834	0,6	4	285,2016
5	Feedup production work	107,520	0,6	4	258,048
6	Welding production work	130,141	0,6	4	312,3384
7	Finishing work	104,332	0,6	4	250,3968
8	Quality control work	110,442	0,6	4	265,0608
9	Painting work	116,674	0,6	4	280,0176

10	Packing delivery work	144,400	0,6	4	346,56

Crash duration calculation is used to accelerate the project by maximizing resources and time on the project with volume = 4920.32 kg / productivity acceleration working hours = 621.5136 kg = 8 days crash duration.

3.2.2 Alternative Job Speed With the Increase of Manpower

The alternative of acceleration project completion by adding manprower to the ducting project is assumed to be 60% of the increase in daily productivity due to the addition of working hours = 621.5136 kg – Normal daily productivity = 258.964 kg / 258.964 kg x 100% = 60% or 0.6. Calculation of labor increase = 60% x 7 people = 4 people. Normal daily productivity calculation = 258,964 kg + $\left(\frac{258{,}964 \text{ kg x } 4 \text{ person}}{7 \text{ person}}\right)$ = 406,943 kg. Here is table 5 productivity acceleration labor addition.

Table 5. Accelerated Productivity After Labor Addition

No	Job Description	Indeks (%)	Early workforce	Labor Addition	Prod. Perc.
1	Engineering drawing work	258,964	7	4	406,943
2	Material procurement work	170,328	2	1	267,658
3	Cutting marking production work	134,901	5	3	211,987
4	Machining production work	118,834	2	1	186,739
5	Feedup production work	107,520	5	3	168,960
6	Welding production work	130,141	6	4	204,507
7	Finishing work	104,332	6	4	163,950
8	Quality control work	110,442	4	2	173,551
9	Painting work	116,674	3	2	183,344
10	Packing delivery work	144,400	3	2	226,914

The calculation of crash duration of work with alternative addition of labor is obtained from the calculation of volume = 4920.32 kg / 406.943 kg productivity acceleration of labor addition = 12 days crash duration.

3.2.3 Normal Cost and Crash Cost Alternative Increase in working hours and labor

Normal cost are the direct costs of completing each project work[19]. In normal times each project is assumed the normal labor cost per day is Rp. 100,000 x 7 initial labor x 2 days = Rp. 1,400,000. Crash cost of adding 4 hours of work for each job is assumed to be Rp. 150,000 + Rp. 100,000 normal daily cost = Rp. 250,000. Calculation of overtime crash cost Rp. 250,000 x 8 days overtime duration x 7 workers = Rp. 14,000,000. While the crash cost of adding labor with normal costs Rp. 100,000 x 4 people adding labor x 12 days crash duration = Rp. 4,800,000.

3.2.4 Relationship of Fault Tree Analysis Results with Critical Path Method

Based on the results of FTA (Fault Tree Analysis) analysis, the main factor causing the delay in ducting projects is in drawing engineering work whose problems related to the agreement of the owner, main contractor and sub contractor, image processing cannot be agreed unilaterally when in the field, because the main contractor and sub contractorare still processing images in accordance with the owner's request and there is a relationship with CPM (Critical Path Method) analysis, there are 10 critical jobs that depend on drawing engineering work will cause project execution time to increase because drawing engineering work is on a critical trajectory and the longest work is delayed in ducting projects.

4. Conclusion

Based on the results of ducting project research PT. FRA uses the FTA method, there is the highest probability value in the basic event based on the calculation of the minimum cut set on engineering

drawing work of 0.0002592 and obtained 4 new steps for the project contractors. Meanwhile, by using the CPM method, an alternative was obtained to accelerate the addition of 4 hours of work (overtime), a duration of 25.00% or 6 days faster and a normal duration of 19 days to 13 days faster and an additional cost of 91.96%, which is IDR Rp. 21,500,000. Meanwhile, the acceleration of the addition of alternative workers, the acceleration of the duration is 38.75% or 5 days faster than the normal duration of 19 days to 14 days and additional costs of 178.57%, namely Rp. 31,200,000[20].

From this study, it can be conduded that the alternative option of adding overtime work hours is more effectively used as an alternative to obtain accelerated duration and generate optimal costs compared to alternative labor additions and the additional costs incurred are also not too large, however it is improtant to conduct further research by analyzing the factors causing the first degree of delay so that the research is more specific and conduct research from the owner's point of view to find out more detailed information about the project cost data.

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