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RE-SCHEDULING OF THE CRUDE OIL STORAGE TANK MSTB T-701D PROJECT USING THE CRITICAL PATH METHOD (CPM) AND CRITICAL CHAIN PROJECT MANAGEMENT (CCPM)

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ABSTRACT

In the MSTB T-701D Crude Oil Storage Tank project, good scheduling is needed so that the project can run smoothly during the process. The most frequently used methods in designing project scheduling are the Critical Path Method and the Critical Chain Project Management. This study aims to compare scheduling results between the traditional CPM and the CCPM methods. The project used in this research analysis is the Crude Oil Storage Tank MSTB T-701D project. The Root Square Error Method (RSEM) is used to find the buffer size. In the scheduling analysis, calculations are carried out manually and with the help of Primavera P6 software as validation for calculating the total float, critical path, and project network. Project scheduling using the Critical Path Method (CPM) is known to be completed in 164 days. Whereas for the CCPM, the project can be completed in 140.1 days plus the RSEM buffer calculation method of 5.29 days, and the total scheduling with CCPM produces 145.3 days. This analysis shows that the traditional CPM method has a larger estimated duration than CCPM with an RSEM sizing buffer. Then a suggestion was made to work on the MSTB T-701D Crude Oil Storage Tank project using the CCPM and RCA methods.

Keywords*: Critical Path Method, Critical Chain Project Management, Root Cause Analysis*

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1. INTRODUCTION

Planning and scheduling is an integral part of determining the success of a project. Scheduling a project needs to be considered in project management to determine the duration of work and what activities are in the project, as well as indicating the time and sequence of project activities so that a logical and realistic schedule is formed (Hidayah, Ridwan, and Cahyo, 2018). Product supply activities have a series of processes before producing a product, from providing raw materials, material processing, production, packaging, and quality control to distributing these products to consumers. So at each stage, it takes labor and costs. Every company always strives for every process that is carried out to run effectively and efficiently so that the benefits that the company gets can be optimal(Waluyo and Pulansari, 2014).

However, often a project experiences delays in the completion process. Poor project time management can cause this (Rio and Herawati, 2022). For the smooth running of a project, management is needed who will manage the project from start to finish, namely project management(Priyanto, Ervadius, and Wahyudi, 2019). Project management is the application of knowledge, skills, tools, and work methods in project activities to meet project requirements (Utamadan and Syairudin, 2020). The main objective of project management is for projects to be implemented efficiently, on time, and to achieve the desired results. Therefore, the role of planning in a project is significant. Everything must start with a plan and be mutually agreed upon between the stakeholders involved in the project (Putri and Bobby, 2020).

PT. XYZ is a company that provides project services in EPC (Engineering, Procurement, and Construction),The EPC (Engineering, Procurement and Construction) project is a type of project that also has the complexity of a construction project, starting from the interdependence between existing activities, overlapping phases between each activity, breaking down activities into more detailed work activities, complexity organizational structure and claims in predictions that arise during the implementation period(Kabirifar and Mojtahedi, 2019). Projects—one of the EPC projects undertaken by PT. XYZ is the Crude Oil Storage Tank MSTB T-701D project. The MSTB T-701D Crude Oil Storage Tank project is a project for making oil tanks with a wholesale work system. The MSTB T-701D Crude Oil Storage Tank project, which is the object of research, has not implemented a good project management concept. Where the engineering activities are not by the schedule (late) of the project plan from the original 21 days to 47 days. Therefore scheduling must be controlled properly and correctly. Because if the engineering activities are delayed, or late, the procurement work can also experience delays.

This inefficient project management concept is influenced by scheduling which still uses conventional or manual Microsoft Excel methods. This manual method is considered ineffective because the project experiences a delay of 13% in engineering activities and can cause losses to the project. The method can be inefficient because the project scheduling process does not consider the relationship between activities and does not explain the critical path of the MSTB T-701D Crude Oil Storage Tank project, which is the object of research. The critical way is the most extended series of activities that must be completed on time to complete the project. Therefore, in this final project, research is carried out using a scheduling method that is much more efficient and optimal when compared to the manual scheduling method. Most of the previous research was conducted on maritime companies for ship repair. No research has ever been conducted focusing mainly on fabrication, design, and construction companies.

The Critical Path Method (CPM) method is a method that is often used in scheduling activities in project management. The CPM method considers the actions required to complete a project and its duration and plans the workforce requirements for a project(Febriana and Aziz, 2021). The CPM method also adds safety time when scheduling time to reduce the risk of delays in a project. However, over time, a new method emerged, namely the Critical Chain Project Management (CCPM) method. Therefore, the authors want to compare the Critical Path Method (CPM) and Critical Chain

Project Management (CCPM) methods (Rahayu and Eliyah Yuliana, 2022).

The Critical Chain Project Management (CCPM) method is used to design and manage projects that focus on the resource requirements for implementing the project. By eliminating safety time, CCPM replaces it by adding buffer time or backup time. This buffer time focuses on completing the project's critical chain. Based on Rizky's research (2022), they were told that the CCPM method replaces safety time with buffer time to guarantee critical chains on time. Buffer time consists of a feeding buffer and a project buffer. These two Buffer times ensure the project schedule's critical chain and integrity(Sugiyanto and Insan, 2022). The most frequently used method is the Root Square Error Method (RSEM) to find the quantity of the feeding buffer and project buffer. In project management science, many techniques are commonly used to solve a problem, including the Critical Path Method (CPM) and Critical Chain Project Management (CCPM) methods (Haryoko *et al.*, 2022)

Delays in project work can become a problem if it cannot be managed and controlled correctly. One of the methods to identify the causes of delays in project work and project control is the Root Cause Analysis (RCA) method with fishbone diagrams to identify the causes of delays in project work based on the 5M model (machine, method, material, manpower or man, and mother of nature) to identify the root cause of the delay in project execution(Al-Zwainy, Mohammed and Varouqa, 2018). The application of RCA is expected to help companies to be able to find out the root causes of events that cause delays in project work(Utamadan and Syairudin, 2020)

Based on the background description above, the author will conduct a scheduling analysis for the Crude Oil Storage Tank MSTB T-701D project at PT. XYZ. The object of research in this final project is scheduling the fabrication and installation processes of the Crude Oil Storage Tank MSTB T-701D project. The methods used are the Critical Path Method (CPM) and Critical Chain Project Management (CCPM) to conduct the scheduling analysis. This research provided a new scheduling option to reduce the risk of delays in the MSTB T-701D Crude Oil Storage Tank project.

2. METHODS

2.1 Problem Identification

Problem identification is carried out to find and identify problems in the field. It is done by discussing with the supervisor so that the problem formulation can be found.

2.2 CPM Method Scheduling

The Crude Oil Storage Tank MSTB T-701D project data will be processed using the critical path (CPM) method. The first stage is to create a project network from the Crude Oil Storage Tank MSTB T-701D project work data. Network Planning following the work breakdown structure of the crude oil storage tank project obtained from company data. Next, determine the critical path using the forward and backward calculation methods to get the critical path and total float or project duration(Bachmid, Fatmah Arsal and Yaqin Nur, 2020).

2.3 CCPM Method Scheduling

Each activity's safety time will be estimated after identifying the critical path in the CPM method. Furthermore, safety time is eliminated to maximize the productivity of workers. After stopping safety time from each activity, the next step is to calculate the size of the buffer to replace safety time. Next is to calculate the project buffer(Dashti *et al.*, 2021). The value is the average total safety time wasted from each activity. Another method is to use the Root Square Error Method (RSEM) by calculating two standard deviations. After entering the project buffer, entering the feeding buffer protects the critical path from delays. The method used to determine it is the same as the project buffer, utilizing the root square error method (RSEM) but only limited to the safety time on the critical path. The result will be placed at the end of the critical path when it meets the critical path (Dzulfitro Tampubolon, Rahman and Haryanto, 2021).

2.4 Root Cause Analysis (RCA)

Root cause analysis diagram as a problem-solving tool, namely a fishbone diagram or fishbone diagram. A fishbone diagram is used to find the causal factors of a characteristic deviation and clearly illustrates the various sources of nonconformities in related products. The principle used to make a cause-and-effect diagram is brainstorming (Ganda, 2021).

3. FINDINGS AND DISCUSSION

3.1. Findings

This study uses the CPM and CCPM methods to minimize project delays. Based on primary data obtained from the company, it is known that there are 133 types of work activities to complete the project, where all work is categorized into seven job categories, namely Contract Award, Kick Off Meeting, Engineering, Procurement, Shop Fabrication, and Testing, Delivery and Mobilization, Installation, Demobilization.

Table 1. *Project Activities of Crude Oil Storage Tank MSTB T-701D project*

ACTIVITY ID	DURATION	PREDECESSORS	SUCCESSORS
1	**1**		2
2	**1**	**1FS+5 days**	**4**
3	**24**		
4	17	2	5,7
5	7	4	8
6	**42**		
7	24	4FS+5 days	23
8	35	5FS+5 days	
9	**41**		
10	**41**		
11	**20**		
12	3	7FS-5 days	13
13	7	12FS-1 day	14
14	4	13FS-1 day	15
15	7	14FS-1 day	16
16	3	15FS-1 day	29.35
17	**20**		
18	7	7FS-5 days	19
19	7	18FS-1 day	20
20	4	19FS-1 day	21
21	7	20FS-1 day	22
22	3	21FS-1 day	35,30
23	**20**		
24	3	7FS-5 days	25
25	7	24FS-1 day	26
26	4	25FS-1 day	27
27	7	26FS-1 day	28
28	3	27FS-1 day	37,43
29	**7**		
30	2	22	31
31	5	30FS-1 day	32
32	1	31FS-1 day	33
33	2	32FS-1 day	34
34	1	33FS-1 day	64
35	**7**	**16**	64
36	**7**		
37	2	22	38
38	5	37FS-1 day	39
39	1	38FS-1 day	40
40	2	39FS-1 day	41
41	1	40FS-1 day	71
42	**7**		
43	2	22	44
44	5	43FS-1 day	45
45	1	44FS-1 day	46
46	1	44FS-1 day	47
47	2	46FS-1 day	48
48	1	47FS-1 day	71
49	**7**		
50	2	28	51
51	5	50FS-1 day	52
52	1	58FS-1 day	53
53	1	51FS-1 day	54
54	2	53FS-1 day	55
55	1	54FS-1 day	78
56	**7**		
57	2	28	58
58	5	57FS-1 day	59
59	1	58FS-1 day	60
60	1	59FS-1 day	61
61	2	60FS-1 day	62
62	1	61FS-1 day	83
63	**7**		
64	2	35,34	65
65	5	64FS-1 day	66
66	1	65FS-1 day	67
67	1	66FS-1 day	68
68	2	67FS-1 day	69
69	1	68FS-1 day	86
70	**7**		
71	2	41,48	72
72	5	71FS-1 day	73
73	1	72FS-1 day	74
74	1	73FS-1 day	75
75	2	74FS-1 day	76
76	1	75FS-1 day	86
77	**7**		
78	2	55	78
79	5	78FS-1 day	79
80	1	79FS-1 day	80
81	2	80FS-1 day	82
82	1	81FS-1 day	86
83	**7**	**62**	**84,93**
84	**7**	**83**	**93.86**

ACTIVITY ID	DURATION	PREDECESSORS	SUCCESSORS
85	**7**		97
86	1	82,76,69,	87
87	7	86SS	88
88	1	87FF	90
89	3		
90	3	88	
91	**79**		
92	**79**		
93	**4**	**83FS+3 days**	**98**
94	**14**		
95	6	118	96
96	12	95FS-4 days	102
97	**14**		
98	6	93	99
99	12	98FS-4 days	116
100	**14**		
101	4	96	102
102	9	101FS-4 days	103
103	10	102FS-5 days	109
104	**4**		
105	3	109	106
106	1	105	114
107	**5**		
108	2	103	109
109	3	108	105
110	**5**		
111	2	106	112
112	3	111	120,125
113	**5**		
114	3	106	115
115	2	114	123
116	**5**		
117	2	99	118
118	3	117	95
119	**5**		
120	3	112.115	121
121	2	120	130
122	**5**		
123	3	115	124
124	2	123	132
125	**5**		
126	3	112.115	127
127	2	126	130
128	**4**		
129	2	124	124
130	2	121.127.129	130
131	**4**		
132	4	124	133
133	**5**	**130**	**-**

3.2. Discussion

3.2.1. Developing Network Planning with the CPM Method

Compiling a CPM network planning results in finding the critical path of all project activities. The critical path consists of several activities with a total float value of less than or equal to zero. To find the result of the total float required forward and backward calculations(Stie, Tuban and Syaikhudin, 2020).

1) CPM Forward Calculation

Forward calculations find ES (Earliest Start) and EF (Early Finish) results. The data required in the forward analysis is the predecessor data from the project. If an activity has more than one predecessor, the most considerable predecessor time is taken. The equation used in the forward calculation is as follows(Arifin and Shadiq, 2019).

$$EF(i\text{-}j)=ES(i\text{-}j)+D(i\text{-}j) \quad (1)$$

2) CPM Backward Calculation

The backward calculation finds the results of the LS (Latest Start) and LF (Latest Finish). The data needed in the countdown is the successor data from the project. If an activity has more than one successor, the smallest successor is taken. The equation used in the forward calculation is as follows(Handayani, Mona and Pebriyanto, 2019).

$$LS(i\text{-}j)=LF(i\text{-}j)+D(i\text{-}j) \quad (2)$$

3) CPM Total Float Calculation

The total float of an activity can be calculated using the latest finish time (LF) minus the earliest finish time (EF). The characteristics of an activity on a critical path or critical path can be known if the total float of an activity is the same as where the activity cannot be postponed. Total float can be found using the following formula (Shadiq, 2020):

$$TF = LF – EF \quad (3)$$

Table 2. CPM Method Critical Path Activities

ACTIVITY ID	ES	LS	EF	LF	TF
1	0	0	1	1	0
2	1	1	7	7	**0**
3					

ACTIVITY ID	ES	LS	EF	LF	TF
4	7	7	24	24	0
5	24	117	31	124	93
6	0	0	0	0	0
7	24	24	53	53	0
8	31	124	71	164	93
9					
10					
11					
12	53	126	51	124	73
13	53	124	59	130	71
14	59	130	62	133	71
15	62	133	68	139	71
16	68	139	70	141	71
17					
18	53	126	55	124	69
19	55	124	61	130	69
20	61	130	64	130	66
21	64	133	70	139	69
22	70	139	72	141	69
23					
24	53	53	51	51	0
25	53	53	59	59	0
26	59	59	62	62	0
27	62	62	68	68	0
28	68	68	70	70	0
29					
30	72	141	74	143	69
31	74	143	78	147	69
32	78	147	78	147	69
33	78	147	79	148	69
34	79	148	79	148	69
35	72	141	79	148	69
36					
37	72	140	74	142	68
38	74	142	78	146	68
39	78	146	78	146	68
40	78	146	79	147	68
41	79	147	79	147	68
42					
43	72	140	74	142	68
44	74	142	78	146	68
45	78	146	78	146	68
46	78	146	78	146	68
47	78	146	79	147	68
48	79	147	79	147	68
49					
50	72	141	74	143	69
51	74	143	78	147	69
52	78	147	78	147	69
53	78	147	78	147	69
54	78	147	79	148	69
55	79	148	79	148	69
56					
57	72	68	74	70	-4

ACTIVITY ID	ES	LS	EF	LF	TF
58	74	70	78	74	-4
59	78	74	78	74	-4
60	78	74	78	74	-4
61	78	74	79	75	-4
62	79	75	79	75	-4
63					
64	79	148	81	150	69
65	81	150	85	154	69
66	85	154	85	154	69
67	85	154	85	154	69
68	85	154	86	155	69
69	86	155	86	155	69
70					
71	79	147	81	149	68
72	81	149	85	154	69
73	85	154	85	154	69
74	85	154	85	154	69
75	85	154	86	155	69
76	86	155	86	155	69
77					
78	79	148	81	150	69
79	81	150	85	154	69
80	85	154	85	154	69
81	85	154	86	155	69
82	86	155	86	155	69
83	79	75	86	82	-4
84	79	82	86	89	3
85					
86	86	155	87	156	69
87	87	156	94	163	69
88	94	163	95	164	69
89					
90	95	161	98	164	66
91	0	0	0	0	0
92	0	0	0	0	0
93	86	85	89	89	0
94					
95	108	108	114	114	0
96	114	114	122	122	0
97					
98	89	89	95	95	0
99	95	95	103	103	0
100					
101	122	122	126	126	0
102	126	126	131	131	0
103	131	131	136	136	0
104	0	0	0	0	**0**
105	141	141	144	144	0
106	144	144	145	145	0
107	0	0	0	0	**0**
108	136	136	138	138	0
109	138	138	141	141	0
110					
111	145	154	147	156	9

ACTIVITY ID	ES	LS	EF	LF	TF
112	147	156	150	159	9
113					
114	145	145	148	148	0
115	148	148	150	150	0
116					
117	103	103	105	105	0
118	105	105	108	108	0
119					
120	150	159	153	162	9
121	153	162	155	164	9
123	150	150	153	153	0
124	153	153	155	155	0
125					
126	150	159	153	162	9
127	153	162	155	164	9
128					
129	155	160	157	162	5
130	157	162	159	164	5
131					
132	155	155	159	159	0
133	159	159	164	164	**0**

Based on the calculation of the total float in Table 2, the critical path of the MSTB T-701D Crude Oil Storage Tank manufacturing project can be identified. Activities included in the critical path have a total float result equal to or less than zero. In this case, the activities included in the critical path have a total value of float = 0. The activities that are on the critical path are 1, 2, 4, 7, 21, 22, .24, 25, 26, 27, 28, 57, 58, 59, 60, 61, 62, 83, 93, 95, 96, 98, 99, 101, 102, 103, 105, 106, 108, 109, 114, 115, 117, 118, 123, 124, 132, 133 with the total duration of the total project is 164 days

3.2.2. Application of the CPM Method in Primavera Software

The first step that must be taken in applying the method to the Primavera P6 software is to enter the data that has been obtained. The data that needs to be entered into the Primavera P6 software is the activity name, activity duration, and predecessor. In implementing scheduling on the Primavera P6, the initial steps taken were to enter the project start date and determine the calendar that corresponds to the docking work of the MSTB T-701D Crude Oil Storage Tank project, namely seven working days with 9 hours of working time. Activities on the critical path can be seen in the Primavera P6 software with a red box on the Gantt chart. Another way to find the critical path is to add the total float and critical columns. If an activity is on the critical path, it has a total float = 0 and the statement "YES" in the critical column. The use of the Primavera P6 software has the objective of validating forward manual calculations, reverse manual calculations, and manual total float calculations. The following output image generated by the software is shown in Figure 1.

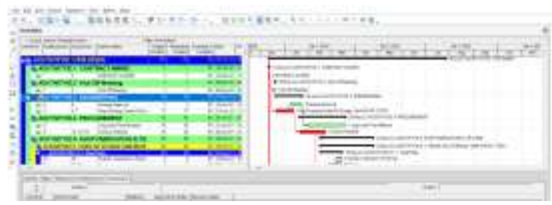

Figure 1. Input data on the Primavera P6 software

3.2.3. Developing Network Planning with the CCPM Method

1) Cutting Safety Time in Activities

Based on interviews with Project Control Staff data on cutting the duration of safety time in 7 job categories, namely Contract Award and Kick Off Meeting activities by 0%, Engineering, Procurement, and Shop Fabrication and Testing by 10%, Delivery and Mobilization by 20%, Installation and Demobilization by 15%.

2) Buffer Calculation

In the CCPM method, the duration of safety time is cut to minimize work duration and maximize existing work. However, cutting the duration also increases the risk of delays. So in the CCPM method, a buffer replaces the loss of safety time in activities(Sugiyanto and Insan, 2022). There are two types of buffers used in CCPM. Project buffer to protect the entire project chain placed at the end of the project chain and feeding buffer to protect critical path activities from delays in activities on non-critical paths set at the end of the non-critical chain that will meet the critical chain(Lianto and Anondho, 2018). The method used to find buffers in this final project is the Root Square Error Method (RSEM). The author uses the RSEM method, considering that the buffer duration results obtained from RSEM are relatively minor compared to other buffer sizing methods. The equation used is as follows(Hasil *et al.*, 2023).

$$(\mathrm{Ui}) = \mathrm{Si} - \mathrm{di} \tag{4}$$

$$\text{Buffer sizing} = \sqrt{\textstyle\sum_{i=1}^{n} (U_I)^2} \tag{5}$$

Definition :

a) U_I = Uncertainty of work duration i
b) Si = Estimated duration of work with safety time i
c) di = Estimated average work time without safety time i
d) n = Lots of work

The project buffer and feeding buffer results in the CCPM method can be obtained as follows.

Table 3. Feeding Buffers

FEEDING BUFFERS				
ACTIVITY ID	S_i	d_i	S_i - d_i	$(S_i - d_i)^2$
1	1	1	0	0
2	1	1	0	0
4	17	15,3	1,7	2.89
7	24	21,6	2,4	5,76
24	3	2,7	0.3	0.09
25	7	6,3	0.7	0.49
26	4	3,6	0.4	0.16
27	7	6,3	0.7	0.49
28	3	2,7	0.3	0.09
57	2	1,8	0.2	0.04
58	5	4,5	0.5	0.25
59	1	0.9	0.1	0.01
60	1	0.9	0.1	0.01
61	2	1,8	0.2	0.04
62	1	0.9	0.1	0.01
83	7	6,3	0.7	0.49
84	7	5,6	1,4	1.96
93	4	3,4	0.6	0.36
95	6	5,1	0.9	0.81
96	12	10,2	1,8	3,24
98	6	5,1	0.9	0.81
99	12	10,2	1,8	3,24
101	4	3,4	0.6	0.36
102	9	7.65	1.35	1.8225
103	10	8,5	1.5	2.25
105	3	2.55	0.45	0.2025
106	1	0.85	0.15	0.0225
108	2	1,7	0.3	0.09
109	3	2.55	0.45	0.2025
111	2	1,7	0.3	0.09
112	3	2.55	0.45	0.2025
114	3	2.55	0.45	0.2025
115	2	1,7	0.3	0.09
117	2	1,7	0.3	0.09
118	3	2.55	0.45	0.2025
120	3	2.55	0.45	0.2025
121	2	1,7	0.3	0.09
123	3	2.55	0.45	0.2025
124	2	1,7	0.3	0.09
126	3	2.55	0.45	0.2025
127	2	1,7	0.3	0.09
129	2	1,7	0.3	0.09
130	2	1,7	0.3	0.09
TOTAL				**25,235**
FEEDING BUFFER (DAYS)				**5.02**

Table 4. Project Buffers

PROJECT BUFFERS				
ACTIVITY ID	S_i	d_i	S_i - d_i	$(S_i - d_i)^2$
1	1	1	0	0
2	1	1	0	0
4	17	15,3	1,7	2.89
7	24	21,6	2,4	5,76
24	3	2,7	0.3	0.09
25	7	6,3	0.7	0.49
26	4	3,6	0.4	0.16
27	7	6,3	0.7	0.49
28	3	2,7	0.3	0.09
57	2	1,8	0.2	0.04
58	5	4,5	0.5	0.25
59	1	0.9	0.1	0.01
60	1	0.9	0.1	0.01
61	2	1,8	0.2	0.04
62	1	0.9	0.1	0.01
83	7	6,3	0.7	0.49
84	7	5,6	1,4	1.96
93	4	3,4	0.6	0.36
95	6	5,1	0.9	0.81
96	12	10,2	1,8	3,24

98	6	5,1	0.9	0.81
99	12	10,2	1,8	3,24
101	4	3,4	0.6	0.36
102	9	7.65	1.35	1.8225
103	10	8,5	1.5	2.25
105	3	2.55	0.45	0.2025
106	1	0.85	0.15	0.0225
108	2	1,7	0.3	0.09
109	3	2.55	0.45	0.2025
114	3	2.55	0.45	0.2025
115	2	1,7	0.3	0.09
117	2	1,7	0.3	0.09
118	3	2.55	0.45	0.2025
123	3	2.55	0.45	0.2025
124	2	1,7	0.3	0.09
132	4	3,4	0.6	0.36
133	5	4,25	0.75	0.5625
TOTAL				**25,235**
PROJECT BUFFER (DAYS)				**5.02**

3) CCPM Forward Calculation

Forward calculations find ES (Earliest Start) and EF (Early Finish) results. The data required in the forward calculation is the predecessor data from the project. If an activity has more than one predecessor, the most significant predecessor time is taken. The equation used in the forward calculation is as follows(Azhari *et al.*, 2021).

$$EF(i\text{-}j)=ES(i\text{-}j)+D(i\text{-}j) \qquad (6)$$

4) CCPM Backward Calculation

The backward calculation finds the results of the LS (Latest Start) and LF (Latest Finish). The data needed in the countdown is the successor data from the project. If an activity has more than one successor, the smallest successor is taken. The equation used in the forward calculation is as follow (Andiyan *et al.*, 2021) s.

$$LS(i\text{-}j)=LF(i\text{-}j)+D(i\text{-}j) \qquad (7)$$

5) CCPM Total Float Calculation

The total float of an activity can be calculated using the latest finish time (LF) minus the earliest finish time (EF). The characteristics of an activity on a critical path or critical path can be known if the total float of an activity is the same as where the activity cannot be postponed. Total float can be found using the following formula(Sinaga and Husin, 2021):

$$TF = LF – EF \qquad (8)$$

Table 5. CCPM Method Critical Path Activities

ACTIVITY ID	ES	LS	EF	LF	TF
1	0	0	1	1	0
2	1	1	7	7	**0**
3	0				
4	7	7	22,3	22,3	0
5	22,3	97.3	28,6	103,6	75
6	0				
7	22,3	22,3	48,9	48,9	0
8	28,6	103,6	65,1	140,1	75
9					
10					
11					
12	48,9	108,2	46,6	105.9	59,3
13	48,9	105.9	54,2	111.2	57
14	54,2	111.2	56,8	113.8	57
15	56,8	113.8	62,1	119,1	57
16	62,1	119,1	63,8	120.8	57
17	0				
18	48,9	108,2	50,2	105.9	55,7
19	50,2	105.9	55.5	111.2	55,7
20	55.5	111.2	58,1	111.2	53,1
21	58,1	113.8	63,4	119,1	55,7
22	63,4	119,1	65,1	120.8	55,7
23	0				
24	48,9	48,9	46,6	46,6	0
25	48,9	48,9	54,2	54,2	0
26	54,2	54,2	56,8	56,8	0
27	56,8	56,8	62,1	62,1	0
28	62,1	62,1	63,8	63,8	0
29	0				

ACTIVITY ID	ES	LS	EF	LF	TF
30	65,1	121.2	66,9	123	56,1
31	66,9	123	70,4	126.5	56,1
32	70,4	126.5	70,3	126,4	56,1
33	70,3	126,4	71,1	127,2	56,1
34	71,1	127,2	71	127,1	56,1
35	65,1	120.8	71.4	127,1	55,7
36	0				
37	65,1	121.2	66,9	123	56,1
38	66,9	123	70,4	126.5	56,1
39	70,4	126.5	70,3	126,4	56,1
40	70,3	126,4	71,1	127,2	56,1
41	71,1	127,2	71	127,1	56,1
42	0				
43	65,1	121.3	66,9	123,1	56,2
44	66,9	123,1	70,4	126.6	56,2
45	70,4	126.6	70,3	126.5	56,2
46	70,3	126.5	70,2	126,4	56,2
47	70,2	126,4	71	127,2	56,2
48	71	127,2	70,9	127,1	56,2
49	0				
50	65,1	121.2	66,9	123	56,1
51	66,9	123	70,4	126.5	56,1
52	70,4	126.5	70,3	126,4	56,1
53	70,3	126,4	70,2	126.3	56,1
54	70,2	126.3	71	127,1	56,1
55	71	127,1	70,9	127	56,1
56	0				
57	65,1	61,2	66,9	63	-3,9
58	66,9	63	70,4	66.5	-3,9

ACTIVITY ID	ES	LS	EF	LF	TF
59	70,4	66.5	70,3	66,4	-3,9
60	70,3	66,4	70,2	66,3	-3,9
61	70,2	66,3	71	67,1	-3,9
62	71	67,1	70,9	67	-3,9
63	0				
64	70,9	127,1	72,7	128.9	56,2
65	72,7	128.9	76,2	132,4	56,2
66	76,2	132,4	76,1	132.3	56,2
67	76,1	132.3	76	132,2	56,2
68	76	132,2	76.8	133	56,2
69	76.8	133	76,7	132.9	56,2
70	0				
71	70,9	127,1	72,7	128.9	56,2
72	72,7	128.9	76,2	132,4	56,2
73	76,2	132,4	76,1	132.3	56,2
74	76,1	132.3	76	132,2	56,2
75	76	132,2	76.8	133	56,2
76	76.8	133	76,7	132.9	56,2
77	0				
78	70,9	127	72,7	128.8	56,1
79	72,7	128.8	76,2	132.3	56,1
80	76,2	132.3	76,1	132,2	56,1
81	76,1	132,2	76.9	133	56,1
82	76.9	133	76.8	132.9	56,1
83	70,9	67	77,2	73,3	**-3,9**
84	70,9	73,3	76.5	78.9	**2,4**
85	0				
86	76.5	132.9	77,3	133.7	56,4
87	77,3	133.7	82.9	139.3	56,4

ACTIVITY ID	ES	LS	EF	LF	TF
88	82.9	139.3	83.7	140,1	56,4
89	0	0	3	0	
90	83.7	137,7	86.1	140,1	54
91	0				
92	0	0	0	0	
93	76.5	75.5	78.9	78.9	
94	0				
95	94.45	94.45	99.55	99.55	0
96	99.55	99.55	105.75	105.75	0
97	0	0	0	0	
98	78.9	78.9	84	84	0
99	84	84	90,2	90,2	0
100	0				
101	105.75	105.75	109,15	109,15	0
102	109,15	109,15	112.8	112.8	0
103	112.8	112.8	116,3	116,3	0
104	0				
105	120.55	120.55	123,1	123,1	0
106	123,1	123,1	123.95	123.95	0
107	0	0	0	0	**0**
108	116,3	116,3	118	118	0
109	118	118	120.55	120.55	0
110	0				
111	123.95	131.6	125.65	133,3	7.65
112	125.65	133,3	128,2	135.85	7.65
113	0				
114	123.95	123.95	126.5	126.5	0
115	126.5	126.5	128,2	128,2	0
116	0	0	0	0	
117	90,2	90,2	91.9	91.9	0
118	91.9	91.9	94.45	94.45	0
119	0				

ACTIVITY ID	ES	LS	EF	LF	TF
120	128,2	135.85	130.75	138.4	7.65
121	130.75	138.4	132.45	140,1	7.65
122	0				
123	128,2	128,2	130.75	130.75	0
124	130.75	130.75	132.45	132.45	0
125	0				
126	128,2	135.85	130.75	138.4	7.65
127	130.75	138.4	132.45	140,1	7.65
128	0				
129	132.45	136.7	134,15	138.4	4,25
130	134,15	138.4	135.85	140,1	4,25
131	0				
132	132.45	132.45	135.85	135.85	0

Based on the calculation of the total float in Table 2, the critical path of the MSTB T-701D Crude Oil Storage Tank manufacturing project can be identified. Activities included in the critical path have a total float result equal to or less than zero. In this case, the activities included in the critical path have a total value of float = 0. The activities that are on the critical path are 1, 2, 4, 7, 21, 22, .24, 25, 26, 27, 28, 57, 58, 59, 60, 61, 62, 83, 93, 95, 96, 98, 99, 101, 102, 103, 105, 106, 108, 109, 114, 115, 117, 118, 123, 124, 132, 133 with the total duration of the total project is 140.1 days. If the buffer is fully used, then the duration will be 145.3.

3.2.4. Application of the CCPM Method in Primavera Software

The CCPM method is the same for overall data input as the CPM method. The first step that must be taken in applying the method to the Primavera P6 software is to enter the data that has been obtained. The data that needs to be entered into the Primavera P6 software is the activity name, activity duration, and predecessor. Reducing the period of each activity in this method causes a more significant risk of delay. Therefore, a buffer or buffer time must be applied to prevent late activities. Buffers must be applied to project time with reduced activity duration to produce a safer schedule. In the process using Primavera P6, entering the buffer value is divided into two stages. The first is joining the value of the feeding buffer, which is placed at the end of the activity on the non-critical path, and the second stage is the project buffer placed at the end of the activity on the critical path in the Primavera P6. The following input data and buffer in the software are shown in Figure 2.

Figure 2. Input buffer in the Primavera P6 software

3.2.5. Buffer Management Analysis

Based on previous calculations and analysis, it was found that the size of the project buffer was 5.29 days. These results will then be divided into three equal measures, which will determine the areas as shown in the table below:

Table 5. Percentage of Project Buffer Duration Usage

Buffer Usage Zone	Duration Used (Days)	Information
0% - 33%	0 – 1.7	There is no action to be taken
34% - 66%	1.8 – 3.5	Plan preventive actions
68% - 100%	3.6 – 5.29	Implement precautions

Based on Table 5, the additional duration is in the zone of consumption of the buffer 0% -33%, the time used or the addition of working days is 1.7 working days and is categorized as no action to be taken on the project because it is still in a safe condition, for the consumption zone the buffer is 34% - 66% duration used or additional working days of 3.5 working days categorized as necessary to plan preventive actions on the project because it increases the burden of project costs through increased duration while for the buffer consumption zone, 67% - 100% duration used or additional working days of 5.29 days work categorized as the need to apply preventive measures because it results in swelling or increasing the burden of project costs through an increase in 5.29 days

3.2.6. Root Cause Analysis (RCA)

One method for identifying the causes of delays in project work and project control is the Root Cause Analysis (RCA) method with cause-and-effect diagrams to identify the causes of delays in project work based on the 5M model (Machine, Method, Material, Man Power or Man, and Mother Nature or Environment). Factors causing delays in the MSTB T-701D Crude Oil Storage Tank manufacturing project were found by brainstorming and grouped into a Fishbone diagram, as shown in Figure 4

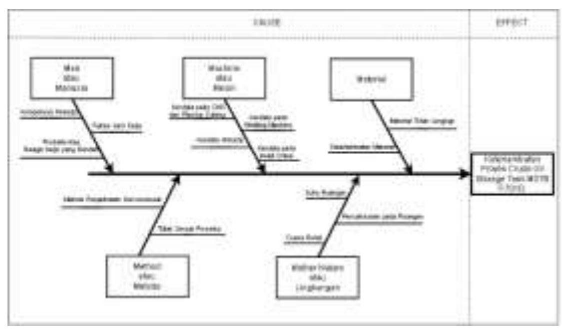

Figure 4. Fishbone Analysis Diagram

1) Man

a. Worker Competency

A worker's skill determines the productivity and efficiency of fabrication and installation activities; the more skilled and responsive, the more productive. Because this is related to skills in marking, cutting, welding, and painting activities, another factor that affects the workers' competence is worker fatigue, which directly impacts the competence of the workers.

b. Hours Factor

shift changes often run irregularly, which results in a direct increase in Idle Time because the loading and unloading activities cannot run. The most common thing is that the workforce ends the shift earlier than it should, resulting in frequent ineffective loading and unloading activities before the shift change.

c. Low Labor Productivity

Based on the results of interviews with workers, the cause of project delays was the behavior of unskilled workers who lacked discipline and did not produce work according to the owner's will. As a result, work handover takes longer due to improvements to work items that have been completed. This is due to the lack of inspections and directions in the field that should be carried out by supervisory consultants and supervisors from contractors regarding the work to be carried out.

2) Machine

a. Constraints on CNC and Plasma Cutting

. In marking and cutting activities, of course, the role of CNC and plasma cutting is very necessary and is always used non-stop in making patterns and cutting materials so the condition of CNC and plasma cutting also requires maintenance to keep the machine in good condition. The maintenance process is often not scheduled regularly, so several cases of damaged CNC and plasma cutting occur.

b. Obstacles to Welding Machine

From the results of observations made, the production capacity of the welding machine because was found that the machine is old. Even though its function is still running well, its performance has certainly experienced degradation. The machine can experience a stop at any time in the middle of production. Thus, these constraints will be increasingly difficult to achieve promptly.

c. Fleet Constraints

From the results of observations made, the lack of maintenance of the fleet is also one of the factors that influenced the failure to achieve the estimated duration due to material and equipment mobilization project activities where the author made observations in the field and found several cases of damage to trucks which were due to lack of maintenance on trucks operating in the area.

d. Obstacles on Head Crane

From the results of the observations made, the removal and lifting of material that exceeds capacity cause damage to head cranes. As a result of damage to the head cranes, the movement of materials becomes hampered, thereby reducing the productivity of the workforce that has been deployed.

3) Material

a. Incomplete Materials

From the results of observations, the material affects production capacity if it is found that the raw material is incomplete during the production schedule, so the production process is on hold due to waiting for the completeness of the raw material. Thus, the entirety of raw materials will be increasingly difficult to achieve promptly to support the fabrication process.

b. Materials Delay

From the results of observations, the cause of delays in the project is the delay in the arrival of materials such as components that have not been ordered or are currently in production. For component goods that have not been produced, it is likely because the supplier is still looking for raw materials to make these goods, which also requires several stages of procurement of goods that need to be passed.

4) Method

a. Conventional Scheduling Method

From the results of observations made, the cause of delays is due to inefficient scheduling methods that still use conventional or manual methods using Microsoft Excel. The method can be less efficient because the project scheduling process does not consider the relationship between activities and does not explain the project's critical path.

b. Not according to procedure

From the results of observations made, the cause of delays in terms of the method is that the welding current and welding speed used are not adjusted to the Welding Procedure Specification when carrying out welding activities which are too large and cause repetition of welding on the tank parts so that further activities are delayed.

5) Mother Nature or Environment

a. Room temperature

From the results of observations made based on conditions in the field, the room temperature in the factory environment, which is hot and less extensive, causes workers to make tank parts feel uncomfortable in doing their job and interfere with employee mobility, causing a lack of efficiency and effectiveness at work.

b. Lighting in the Room

From the observations made based on conditions in the field, room lighting makes workers less focused on following the path to be welded, which results in over-limit welding or the weld going off the path that must be welded.

c. Bad weather

delivery and mobilization activities often experience problems due to bad weather. Bad weather, such as rainstorms and big waves at sea, can hinder the shipping process. However, the weather factor is difficult to predict, making it difficult to control.

Based on the problems faced by PT. XYZ was working on the MSTB T-701D Crude Oil Storage Tank manufacturing project; a suggestion was given to use the CCPM and RCA methods and document learning and project knowledge as a guide to achieving success in the project through improving project performance so that the company can complete the project by the work contract agreed upon with the project owner.

4. CONCLUSION AND SUGGESTION

4.1. Conclusion

Based on the results of the scheduling analysis on the Crude Oil Storage Tank MSTB T-701D project at PT. XYZ uses the CPM, CCPM, and Fishbone diagram methods. The following conclusions are obtained:

The resulting duration based on scheduling using the CCPM (Critical Chain Project Management) method is 145.3 days, 18 days faster, which is 11% compared to the company and CPM methods, which is 164 days. Based on the results of field observations, reference data, and fishbone diagram analysis, it can be concluded that the factors causing the delay in the MSTB T-701D Crude Oil Storage Tank manufacturing project include man (Worker Competence, Working Hours Factor, and Low Labor Productivity), machine (Constraints on CNC and Plasma Cutting, Obstacles on Welding Machine, Fleet Constraints, and Head Crane Constraints), material (Incomplete Material and Material Delay), method (Conventional and Non-Procedural Scheduling Methods), and mother-of-nature (Room Temperature, Room Lighting, Bad Weather).

4.2. Suggestions

Companies can apply the CCPM schedule in scheduling subsequent projects accompanied by the company's socializing, training, and control efforts.

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