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Implementation of Critical Chain Project Management Method on Controlling the Pipeline Project

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***Abstract*— In the implementation of construction projects, the incompatibility between the plan and the actual schedule that causes additional time and cost is often occurring. The Pipeline Project started in July 2022 and is scheduled for completion in November 2022. However, in actuality, the project finished in July 2023. Based on this case, an acceleration method needs to be implemented so that the project can be completed quickly and efficiently. One of the methods applied is Critical Chain Project Management (CCPM). Scheduling is carried out using the actual duration of the project that is applied with CCPM. The actual duration of the project is 318 days. Furthermore, by using the CCPM, the duration has become 216 days. So, by using the CCPM, the project is completed 32.08% faster than the actual duration of the project. Based on the results of the analysis, applying the CCPM method can make an optimal duration of the project.**

***Keywords*; Critical Chain Project Management, Duration, Scheduling**

I. INTRODUCTION

In a project, the incompatibility between the plan and the actual schedule causes additional time and cost are often occurring (Ramadhan, A. R., 2021). Planning and scheduling in the execution of a project is an important part of determining the overall success of the project (Subakir, & Sugiyanto, 2022). As a project in general, some obstacles result in delays in the completion of this project. The lateness that occurred was caused by several factors such as the lateness of the material incoming, the bridge project by another contractor, some trees that affected the pipeline, the weather, and the lack of manpower and tools.

A common problem in the current construction segment is that there are frequent changes in the implementation phase that cause the completion of the construction process to retreat from the initial schedule (Kim, S. H, 2012). As a result, the project is not running smoothly, resulting in an additional cost that exceeds the planned, causing the project process to be delayed even to the point of crashing. Good project control is an important thing to do to avoid additional work and costs incurred by the project (Suherman, 2016).

The pipeline project started in July 2022 and is scheduled for completion in November 2022. However, in actuality, the project finished in July 2023 with a total duration is 318 days. Based on this case, this research will be carried out to control the pipeline project using Critical Chain Project Management (CCPM).

Critical Chain is a project planning and processing model that focuses on the need for resources to implement a project because the Critical Chain differs in position from the Critical Path and PERT methods that emphasize working orders and strict planning settings (Arvianto et al., 2015). The use of CCPM methods in project execution scheduling can optimize the schedules that have already been created due to the possibility of multitasking, Parkinson’s law, student’s syndrome, and then safety time being removed subsequently into the form of a buffer (Wardana, R. A., 2020).

In this method, the safety time that is normally placed on each activity will be removed and replaced with the buffer time placed at the end of the critical chain as a backup time on the entire project. If

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uncertainty occurs during the project execution, it can be anticipated with the existence of buffer time to avoid delays (Nasution, 2014).

II. RESEARCH METHODOLOGY

The phase in this research began by making the Work Breakdown Structure of the project. After that, scheduling the actual duration to get the actual Schedule. Then, scheduling the project using the CCPM method to get the duration and the critical path of the project.

2.1 Work Breakdown Structure

The first step is to make a WBS. Work Breakdown Structure (WBS) is a grouping of work elements shown in graphic form to organize and divide the overall scope of a project (Rev, 2003). The functions of the WBS are to group the work and work details of a project to facilitate the process of making a schedule (Efendi, 2020). The WBS is a basic document in project management because it provides a basis for planning and setting project schedules, costs, and changes (Schwalbe, K., 2004).

2.2 Critical Chain Project Management (CCPM)

Critical Chain Project Management (CCPM) is a project planning and control method developed from a methodology called the Theory of Constraints (TOC) that is applied to projects to improve future project performance (Goldratt, E. M., 1997). In a variety of projects, Critical Chain Project Management is defined as the longest chain of interrelated events, where the interrelationship lies in the work or resources that interrelate (Sugiyanto, 2021).

A construction project needs to be scheduled in advance to allocate time, costs, and resources according to the company's budget (Larasati, D. A., & Sutopo, W., 2020). In each work, several obstacles result in low project planning performance. One of the main causes is the amount of safety time added to the project scheduling (Azis et al., 2017). This is due to consideration in preventing the risk of delayed completion in the time estimates of each work. The problem of changing the safety time because of too much, then with the CCPM method updated by replacing it with a buffer time that functions to avoid the uncertainty that will arise and cause a delay in the completion of the project (Azis et al., 2017). The CCPM method is also used to avoid human behavioral problems such as student’s syndrome, Parkinson’s law, multitasking, and overestimated activity durations (Santosa, 2009).

The CCPM is also suggested by the "Project Management Body of Knowledge" (PMBOK) as a breakthrough in a revolutionary way of thinking that can be used to determine how to accelerate project completion, improve scheduling capabilities, and reduce the budget that already set (Ramanda & Arvianto, 2015).

2.3 Decreasing the Work Duration

The first step in applying the CCPM method is to reduce the duration of each work by 50% of the actual duration or use cut and paste method (C&PM). This reduction aims to eliminate the safety time so that problems such as student’s syndrome, Parkinson’s law, multitasking, and over-estimated activity durations can be eliminated (Santosa, B., 2009).

2.4 Adding the Buffer Time

Buffer time management is the basis for managing activities in the critical chain of project scheduling. Buffer time management can provide insights into considerations about resource constraints and focus on the causes of uncertainty in project management. Scheduling without consideration of resource limitations should be done in a project because the time to start each activity is influenced by the availability of resources (Soeharto, 1999).

Reducing the duration of activity on this method leads to an increasing risk of delay. Therefore, it requires a buffer or retention time to be applied so that the activity is not late. In Critical Chain Project Management (CCPM) methods, the addition of buffer time is useful for protecting the critical chain in project scheduling (Siswanto, A. B., & Salim, M. A., 2015).

To obtain accurate buffer calculation, use the root square error method (RSEM). This method is the same as calculating two standard deviations by inserting durations of CPM (S) and CCPM (A) that are greater than 50% of the safe estimate. The buffer size is obtained by

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solving the equation (1) (Newbold, R. C., 1998).

$$2\sigma = 2 \times \sqrt{\left(\frac{S1-A1}{2}\right)^2 + \left(\frac{S2-A2}{2}\right)^2 + \cdots + \left(\frac{S\ -A}{2}\right)^2} \quad (1)$$

Description:
2σ = Buffer Time size
S = CPM Duration
A = CCPM Duration

2.5 Calculating the Feeding Buffer

The feeding buffer is useful to keep activity performance from project scheduling uncertainty that can change to activities in the non-critical path and does not affect the interrelated critical path. Furthermore, the feeding buffer also serves as a backup time that will protect and maintain the performance of critical path activity from changes due to scheduled uncertainties and if there is a delay in the nonspecific path activity. Feeding buffers are placed at the intersection between non-critical and critical chains (Malau, 2019).

2.6 Calculating the Project Buffer

After calculating the feeding buffer, the next phase is to calculate the project buffer. This buffer is added at the end of the project to protect the end time of its completion. Project buffers are placed in the end phase of a project after work on the last critical chain (Malau, A. Z., 2019).

III. RESULT AND DISCUSSION

3.1 *Define*

The pipeline project started in July 2022 and is scheduled for completion in November 2022. However, in actuality, the project finished in July 2023 with a total duration is 318 days. Based on this case, this research will be carried out to control the pipeline project using Critical Chain Project Management (CCPM).

3.2 *Work Breakdown Structure*

WBS on this Pipeline Project is divided into nine scopes including Preparation Work, Soil Work, Thrust Block Work, Box Service Connection Work, Road Crossing Protection Work, Support Work, Piping Work, Horizontal Directional Drilling Work, and Commissioning which can be seen in Figure 1.

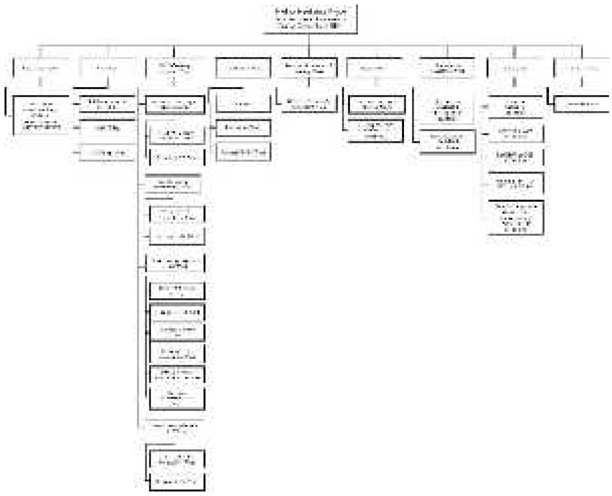

Figure 1. Work Breakdown Structure

3.3 *Scheduling the Actual Duration*

The actual duration schedule starts from July 2022 to July 2023, it's for about ±12 months or 318 days. All works must be scheduled according to the sequence of works. The current duration scheduling using Microsoft Project can be seen in Figure 2.

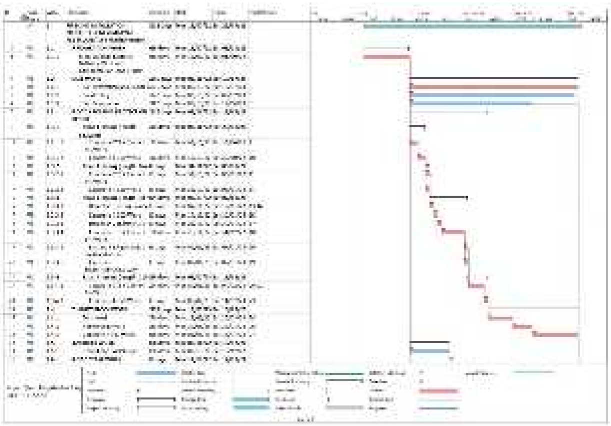

Figure 2. Actual Duration Scheduling

3.4 *CCPM Scheduling*

In CCPM scheduling, several stages need to be analysed including reducing the duration of the activity, calculating the feeding buffer and project buffer, and making network planning.

3.5 *Decrease the Work Duration*

The duration reduction is done on each work by 50% of the actual duration or using the cut and paste method (C&PM) that can be seen in Table 1.

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Table 1 Data of Decreasing the Work Duration

Activity	Duration (CPM)	Duration (CCPM)
Preparation Work		
Mob, Demob, Material Delivery, Workers' Compensation, and Project Management	66	33
Soil Work		
Soil Excavation and Backfilling	246	123
Sand Filling	240	120
Soil Compaction	180	90
Road Crossing Protection Work		
Road Crossing (length: 54,42 m)		
Concrete CTB + Cement 6% Work	12	6
Concrete K-350 Work	12	6
Road Crossing (length: 8 m)		
Concrete CTB + Cement 6% Work	6	3
Concrete K-350 Work	6	3
Road Crossing (length: 18 m)		
Demolish Existing Paving	6	3
Concrete K-350 Work	6	3
Demolish Concrete CTB	6	3
Concrete CTB + Cement 6% Work	30	15
Existing Paving + Sand 5 cm Installation	6	3
Kansteen Slipform/Precast Work	6	3
Road Crossing (length: 110 m)		
Concrete CTB + Cement 6% Work	24	12
Concrete K-350 Work	6	3
Thrust Block Work		
Formwork	36	18
Reinforcing Work	30	15
Concrete K-350 Work	66	33
Permit and Social Cost		
Permit and Social Cost	60	30
Road Stake Work		
Road Stake Work	6	3
Horizontal Directional Drilling Work		
HDD HDPE Pipe PN 12,5, Ø600 Work	72	36
Support Work		
Thick Plate 12 mm + Welding Work	6	3
U-Clamp Dia. 30 + Bolt per 5 m Installation	12	6
Box Service Connection Work		
Box Service Connection 1500x17000x2650 Installation	12	6
Cover Iron Cast 2000x1500 Installation	6	3
Piping Work		
Fitting and Accessories Installation	84	42
Gate Valve Ø24" Installation	162	81
Flexible Joint Ø24" Installation	162	81
HDPE Pipe PN 12,5, SDR 13,6, PE 100, Ø600 Installation	246	123
Black Steel Pipe Ø600 IDE SCH 20 + Cement Lining AWWA C205 Installation	246	123
Commissioning		
Hydrostatic Test	6	3

The critical path of CCPM activities on the Pipeline Project is A-B-AF, A-E-F-G-H-I-J-K-L-M-N-O-P-Q-R-S-AF with a total duration of 159 days.

3.6 *The Calculation of the Feeding Buffer*

Buffers are added to project time whose duration of activity is shortened to generate a safer schedule. To obtain accurate buffer calculation, use the root square error method (RSEM) which can be seen in the following example of buffer time calculation. This is the example of buffer time calculation on Sand Filling work:

$$2\sigma = 2 \times \sqrt{\left(\frac{S1 - A1}{2}\right)^2 + \left(\frac{S2 - A2}{2}\right)^2 + \cdots + \left(\frac{Sn - An}{2}\right)^2}$$

$$2\sigma = 2 \times \sqrt{\left(\frac{240 - 120}{2}\right)^2}$$

$$2\sigma = 2 \times 60$$

$$2\sigma = 120 \text{ hari}$$

Based on the calculation above, the total buffer time on the Sand Filling work is 120 days.

The following table 2, table 3, and table 4 are the results of the feeding buffer calculations.

Table 2 Feeding Buffer on Non-Critical Path C

Kode	Activity	Duration (CPM)	Duration (CCPM)	$((S-A)/2)^2$
	Soil Work			
C	Sand Filling	240	120	3600
	Total			**3600**
	***Feeding Buffer* (hair)**			**120**

Table 3 Feeding Buffer on Non-Critical Path D

Kode	Activity	Duration (CPM)	Duration (CCPM)	$((S-A)/2)^2$
	Soil Work			
D	Soil Compaction	180	90	2025
	Total			**2025**
	***Buffer Time* (hair)**			**90**

Table 4 Feeding Buffer on Non-Critical Path T-U-V-W-X-Y-Z

Kode	Activity	Duration (CPM)	Duration (CCPM)	$((S-A)/2)^2$
	Permit and Social Cost			
T	Permit and Social Cost	60	30	225
	Road Stake Work			
U	Road Stake Work	6	3	2,25
	Horizontal Directional Drilling Work			
V	HDD HDPE Pipe PN 12,5, Ø600 Work	72	36	324
	Support Work			
W	Thick Plate 12 mm + Welding Work	6	3	2,25
X	U-Clamp Dia. 30 + Bolt per 5 m Installation	12	6	9
	Box Service Connection Work			
Y	Box Service Connection 1500x17000x2650 Installation	12	6	9
Z	Cover Iron Cast 2000x1500 Installation	6	3	2,25
	Total			**573,75**
	***Buffer Time* (hair)**			**47,91**

3.7 *The Calculation of Project Buffer*

After calculating the feeding buffer, the next phase is to calculate the project buffer which can be seen in Table 5.

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Table 5 Project Buffer on Critical Path A-E-F-G-H-I-J-K-L-M-N-O-P-Q-R-S-AF

Kode	Activity	Duration (CPM)	Duration (CCPM)	$((S-A)/2)^2$
Preparation Work				
A	Mob, Demob, Material Delivery, Workers' Compensation, and Project Management	66	33	272,25
Road Crossing Protection Work				
	Road Crossing (length: 54,42 m)			
E	Concrete CTB + Cement 6% Work	12	3	9
F	Concrete K-350 Work	12	3	9
	Road Crossing (length: 8 m)			
G	Concrete CTB + Cement 6% Work	6	1,5	2,25
H	Concrete K-350 Work	6	1,5	2,25
	Road Crossing (length: 18 m)			
I	Demolish Existing Paving	6	1,5	2,25
J	Concrete K-350 Work	6	1,5	2,25
K	Demolish Concrete CTB	6	1,5	2,25
L	Concrete CTB + Cement 6% Work	30	7,5	56,25
M	Existing Paving + Sand 5 cm Installation	6	1,5	2,25
N	Kansteen Slipform/Precast Work	6	1,5	2,25
	Road Crossing (length: 110 m)			
O	Concrete CTB + Cement 6% Work	24	6	36
P	Concrete K-350 Work	6	1,5	2,25
	Thrust Block Work			
Q	Formwork	36	18	81
R	Reinforcing Work	30	15	56,25
S	Concrete K-350 Work	66	33	272,25
Commissioning				
AF	Hydrostatic Test	6	3	2,25
	Total			**812,25**
	Buffer Time (hari)			**57**

From the calculations as shown in Table 5, the project buffer is 57 days which can be included in the schedule of the CCPM method (159 days) so that the total duration of the scheduling with the CCPM method is 216 days. The schedule of CCPM duration with the addition of buffer time can be seen in Figure 3.

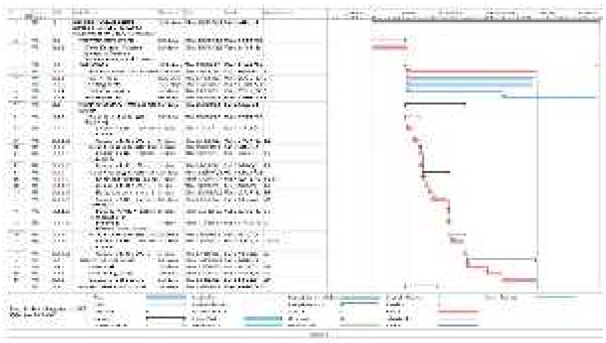

Figure 3. CCPM + Buffer Scheduling

From the advanced calculations, the reverse calculations, and the total float, the network diagram of CCPM is obtained with the addition of buffer time as in Figure 4.

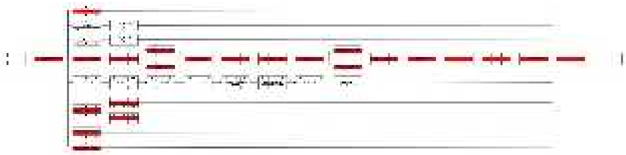

Figure 4. Network Diagram of CCPM + Buffer Time

Based on the results of the duration discussed earlier, it has been proven that scheduling using the Critical Chain Project Management (CCPM) method produces a shorter duration than the actual duration of the project. The following Table 6 represents a comparison of actual duration results with the duration of CCPM scheduling on the Pipeline Project.

Table 6 The Comparison between the Actual Duration and CCPM Result

Methods	Duration (day)
Actual Duration	318
CCPM	216

The calculation results from the actual duration are 318 days. Furthermore, using the CCPM, the duration is 216 days. So, by using the CCPM, the project is completed 32.08% faster than the actual duration.

IV. CONCLUSION

Based on the results of the analysis that has been carried out and discussed, the following conclusions are obtained:

1. Work Breakdown Structure on the Project Pipeline Installation from Sembayat Reservoir to Ground Water Tank JIIPE is divided into 9 scopes, at each scope has its respective stages of work. These nine scopes are Preparation Work, Soil Work, Road Crossing Protection Work, Thrust Block Work, Horizontal Directional Drilling Work, Support Work, Box Service Connection Work, Piping Work, and Commissioning.
2. The comparison of duration between the actual duration and the duration of CCPM

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is that the actual duration of the project is 318 days. While the CCPM method obtains a duration that is 216 days. So, with the CCPM method, the project is completed 32.08% faster than the actual duration. Based on the results of the analysis, applying the CCPM method can make an optimal duration of the project.

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