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Implementation of the Critical Chain Project Management (CCPM) Model for Improving Time and Cost in a Project for House Type 36

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Abstract

Purpose: This study was conducted on a housing project in Type 36 Housing using the Critical Chain Project Management (CCPM) approach. The objective of this research was to achieve a more effective project timeline and a more efficient total project cost.

Methodology: By eliminating 50% of the safety time, the method minimizes the safe time to achieve a 50% probability of completion without additional safety time using Critical Chain Project Management or CCPM in this project.

Results: This approach results in a reduction of the project completion time from the original 18 working days to 15 working days. Additionally, this implementation leads to cost savings, with the calculated daily cost amounting to Rp.10,907,170.03. Through the application of Critical Chain Project Management, a 4-day Feeding Buffer and an 11-day Project Buffer were established. As a result, the completion time for the Type 36 house construction is reduced to 15 days, which is 3 days shorter than the initial project schedule of 18.

Conclusions: The use of the Critical Chain Project Management (CCPM) method in the Type 36 house construction project reduces the completion time from 18 days to 15 days, with a 4-day Feeding Buffer and an 11-day Project Buffer. The Cut & Paste method reduces 50% of safety time, preventing cost overruns. As a result, the daily project cost is Rp 10,907,170.03.

Limitations: This analyzing just focus on critical process but not for opportunity job can be reduce for more improvement. And this research only focus in Construction Project.

Contribution: This research can be use for practical in the project that have critical job need to prepare and control to achive project target, with cost reduction for Rp.10,907,170.03 and project time reduction for 3 days.

Keywords: *CCPM, Cost, House Type 36, Improving, Time.*

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1. Introduction

Improvement within a company is an ongoing task that must be undertaken by all stakeholders, focusing on both time and cost (Fazrin & Ludiya, 2023; Maryadi, Tamalika, Ardaysi, Hermanto, & Azhari, 2023).. This can be achieved by mitigating waste in the company's business processes. The ultimate goal is to enhance the company's performance and competitiveness in relation to other companies (Mardhiana, Yuliansyah, Puspita, & Dewi, 2023; Maryadi, Tamalika, Ardaysi, et al., 2023; Nurhidayati et al., 2021). Current issues in the construction sector, particularly during the project development and execution phases, often result in changes that cause delays in completion. Consequently, the project timeline does not align with the initial planning schedule (Rozi, Aslami, & Dharma, 2024). Additionally, there is a waste of working time, leading to increased material and labor costs, along with delays in material availability. Unpredictable natural conditions or weather, as well as suboptimal human resource quality, further exacerbate these delays (Mediaty, Usman, Mawa'Pangraran, Nadhifa, & Irianto, 2024; Tamalika, Maryadi, Hermanto, Fuad, & Alamsyah, 2022). A project schedule is a tool that can indicate when each activity takes place, thereby enabling control over the overall execution of the project. In other studies, planning or allocating time for each task to complete any project optimally is achieved by considering existing constraints (Sinaga & Husin, 2021a). The construction project comprises several specifically planned tasks with set objectives and constraints. To achieve these objectives, project managers develop execution plans and schedules. Each construction project requires a specific timeframe for completion (Tamalika & Fuad, 2022). To ensure a project is completed on time, several factors are essential, one of which is effective time management (Naidu & Angadi, 2018). Time in a project can be optimized with the aim of reducing both costs and the overall project duration. Proper feasibility calculations and analysis are among the methods to enhance the assessment for achieving the targets of a project or investment (Marwan, Anderson, Tamalika, Maryadi, & Ardaysi, 2024).

Subsidized house is a government initiative to provide affordable and habitable homes, with financial assistance from the Indonesian government. The aim is to effectively create public housing, including various types of houses, one of which is Type 36 (Kholil, Alfa, & Hariadi, 2018). Several Type 36 subsidized housing projects have been implemented, often using the CPM (Critical Path Method) or PERT (Program Evaluation and Review Technique) methodologies (Fatikawati, Basla, & Safiah, 2022; Maryadi, Tamalika, Hermanto, & Wongiawan, 2023; Rakasyiwi, Witjaksana, & Tjendani, 2022). This study will focuses on a subsidized house project funded by the Indonesian government and carried out by a private developer in Palembang, South Sumatra. The study employs the Critical Chain Project Management (CCPM) approach to improve the project's cost efficiency and completion time.

2. Literature Review

In the field of project management, a scheduling method has recently evolved to address uncertainty and mitigate its negative impacts on project completion, as well as to execute other projects without requiring additional resources. This method is known as Critical Chain Project Management (CCPM) (Jo, Lee, & Pyo, 2018). Critical Chain Project Management (CCPM) was first introduced by Eliyahu M. Goldratt as an enhancement of the Theory of Constraints (TOC) model, which focuses on improving a project case by managing and controlling potential uncertainties (Kuo, Chang, & Huang, 2009). The ultimate goal is to enhance overall project performance in terms of time and cost. Critical Chain is a method for designing and managing projects that emphasizes the necessity of resources for project execution (Mariana & Wijaksono, 2021). CCPM is a project planning method that focuses on the resources needed to complete project tasks. This method is implemented by eliminating multitasking, the student syndrome, and Parkinson's law, while also incorporating buffers at the end of the project (Andiyan, Putra, Rembulan, & Tannady, 2021).

In previous research, Critical Chain Project Management (CCPM) has been identified as a scheduling method that can provide an alternative solution to schedule control issues. This method is implemented by eliminating multitasking, the student syndrome, and Parkinson's law, while also incorporating buffers at the project's end. This study aims to compare the CCPM method with the Critical Path Method (CPM) (Taghipour, Seraj, Amin, & Changiz, 2020).

The advantages of the Critical Chain Project Management (CCPM) method include the ability to enhance project processes, resulting in faster completion. Even 'critical tasks' assigned when the project faces issues can be effectively resolved. Solutions to problems, such as trade-offs (efficiently balancing cost and time) and crash programs (additional costs required to accelerate project completion) (Wang, Chan, & Yeung, 2017). Completing individual project activities is not the primary goal, as the CCPM approach prioritizes the success of the entire project. Therefore, the CCPM approach eliminates safety time from a single activity and focuses on completing the project's critical chain. To ensure the timely completion of the critical chain, the CCPM method replaces safety time with buffer time. Buffering time includes item buffering. Feed buffering is the buffer time that connects non-critical chain activities with critical chain activities . Additionally, feed buffers can serve as reserve time if non-critical chain activities are delayed. The project buffer is the buffer time placed at the end of the project's critical chain as a reserve time for the entire project. These two buffer times ensure the integrity of the critical chain and the overall project schedule (Sinaga & Husin, 2021b). Work estimation in Critical Chain requires changes in both individual and organization behavior to succeed (Ma, Jiang, Zhu, & Jia, 2019).

2.1 Job Estimate

Based on (Anastasiu, Câmpian, & Roman, 2023) this method uses two duration/time parameters. The first parameter is the duration that includes idle time to protect against resource delay uncertainty, denoted by the letter S (safe estimate). The second parameter, denoted by the letter A, represents the duration without any idle time. In this study, A is assumed to be the duration with the maximum output rate. As an additional constraint, it is assumed that all activities operate at maximum capacity, with no disruptions from external factors. The difference between the two parameters (D) is formulated as follows:

$D = S - A$ ………………………… (1)

Where:

A = duration without any buffer time.

S = duration includes buffer time to protect against resource delay uncertainties (Safety time)

Amount of the difference is influenced by the variation in activity durations. The required buffer size is then defined as the sum of the square roots. This method assumes that each project activity is independent. Based on these uncertainties, safety time must be added to all project activities to mitigate the risk of delays (Deb, Dey, & Balas, 2019). However, this additional time increases the total project duration. Therefore, it is crucial to minimize the addition of extra time. When adding extra time, several new issues arise. In the CPM method, human behavior problems are often ignored, but in the CCPM method, these issues are addressed during both the planning and execution phases, as they significantly impact the project's continuity (Anastasiu et al., 2023). These issues include Student's Syndrome, Parkinson's Law, Multitasking, and Overestimated Activity Durations:

1. Student’s Syndrome
   As the name suggests, Student’s Syndrome is based on the behavior of students who tend to complete their assignments the night before they are due. Knowing the safety time of a task, they prioritize higher-priority and more urgent tasks. CCPM experts suggest that eliminating safety time from activity durations will remove Student’s Syndrome. If there is no time to waste, the task must be completed as quickly as possible.
2. Parkinson’s Law
   A traditional project is emphasized not to be late, but workers do not receive promotions for completing projects earlier than the set deadline. This reality encourages the effects of hidden safety, Student’s Syndrome, and Parkinson’s Law.
3. Multitasking
   The common practice of working on two or more tasks simultaneously, switching between them without completing the previous one, is often done to appear better in front of supervisors and please customers. Multitasking reduces productivity and lowers the quality of work, potentially leading to job loss.
4. Overestimated Activity Durations
   CCPM addresses several issues by incorporating buffers into the project schedule. Unlike traditional methods that add safety time to each activity, CCPM reduces the project duration by eliminating safety time from each scheduled activity. For further clarification. See Figure 1 below

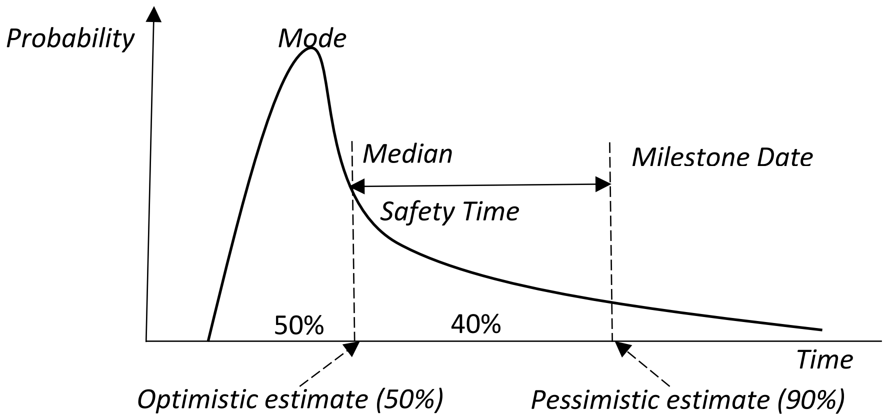

Figure 1. The Distribution of Activity Durations

Reducing activity durations in this method increases the risk of delays. Therefore, buffers or buffer time must be applied to prevent activities from being delayed. Buffers are added to the project timeline where activity durations are reduced, resulting in a safer schedule.

1) Project Buffer
   As mentioned in traditional project scheduling, safety time is incorporated into several activities. In CCPM, this safety time is consolidated into a Project Buffer. This buffer is added at the end of the project to protect the final completion time.
2) Feeding Buffer
   Feeding buffers are inserted to protect critical path activities from delays in non-critical path activities. These buffers are added at the end of non-critical path activities.
3) Resource Buffer
   The Resource Buffer is the only non-time buffer. Its function is to signal and provide a contingency mechanism for resources to be prepared in advance when needed by critical path activities. Resource buffers are inserted into activities where critical path activities release resources of different types.

Figure 2 demonstrates the use of buffers in the Critical Chain Project Management (CCPM) method. The Feeding Buffer (FB) is placed at points where non-critical path activities intersect with critical path activities. The Resource Buffer (RB) is inserted before critical activity C2 because this activity utilizes resources different from those used by activity C1. The Project Buffer (PB) is positioned at the end of the project (Yuliarty, Novia, & Anggraini, 2021).

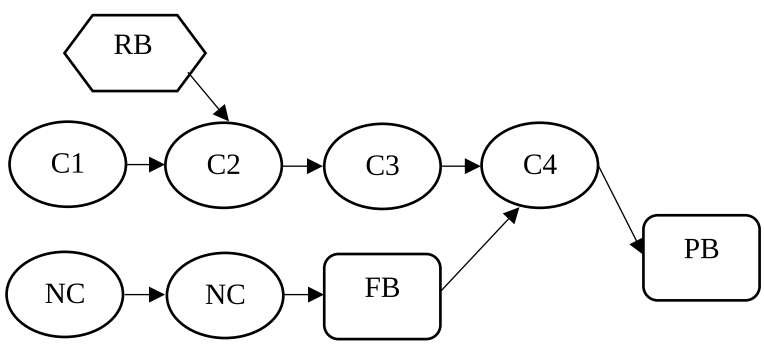

Figure 2. Buffer for CCPM

2.2 Determining the Size of Buffer

To determine the buffer size, two methods can be employed: the Copy and Paste Method (C&PM) and the Root Square Error Method (RSEM), also known as the Sum of Squares (SSQ). Asserted that 50% of the discarded safety time should be used for the project buffer, while 50% of the discarded safety time from the longest non-critical activity should serve as the feeding buffer. An example is shown in Figure 3, where in a critical chain with three activities, each task has a safety time of 20 days, derived from a 50% reduction of the total activity time of 40 days. The project buffer has a value of 30 working days, which is the buffer size added at the end of the critical chain, which has a duration of 60 working days (Adibhesami, Ekhlassi, Mohebifar, & Mosadeghrad, 2019).

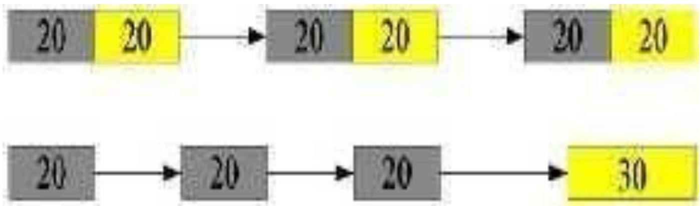

Figure 3. Buffer calculation using C & PM

3. Research Method

In this study, the author examines the control of project timelines during the execution phase by applying the Critical Chain Project Management (CCPM) method in a development project undertaken by a developer in Palembang City. The methodology is outlined as follows:

1) Data Collection: Data is directly gathered from the project, encompassing daily reports that are consolidated into monthly reports. These reports include detailed lists of costs, wages, and completion times.
2) Data Classification: The collected data is categorized based on planning, measurement, and scheduling times.

4. Result and Discussion

At the initial stage, data is obtained from the budget plan for a Type 36 house project, which is a government-subsidized house. This data is provided by the developer and can be seen in Table 1 below.

Tabel 1. Calculation of the Bill of Quantities (BOQ) or "RAB" for Type 36 House and Description of Work Duration

No	Job Description	Work load (Rp)	Job Code	Previous Job
1	Ground Working	4,501,329.26	A	-
2	Pondation	10,234,038.00	B	A
3	Stucture	648,989.33	C	B
4	Wall	76,930,402.40	D	C
5	Stone	885,000.00	E	B
6	Art list	476,954.80	F	E
7	Installation of Frames	10,800,000.00	G	F
8	Work on Beam Formwork	3,482,889.03	H	B
9	Work on Terrace Wall	2,050,035.03	I	H
10	Roof	25,346,080.70	J	I
11	Plavon	5,920,276.00	K	D - G
12	Floor	9,163,193.25	L	G - F
13	Painting	10,643,753.28	M	K - L
14	Sanitation and Piping	10,336,427.50	N	G - L
15	Elctrical Instalation	24,459,692.00	O	J
16	Finishing	450,000.00	P	M - N - O
	Total	**196.329.060,57**		

From the table, the critical path can be identified, as shown in tabel 1 above, the critical path consists of activities A - B - C - D - K - M - P, resulting in a project duration of 18 days.

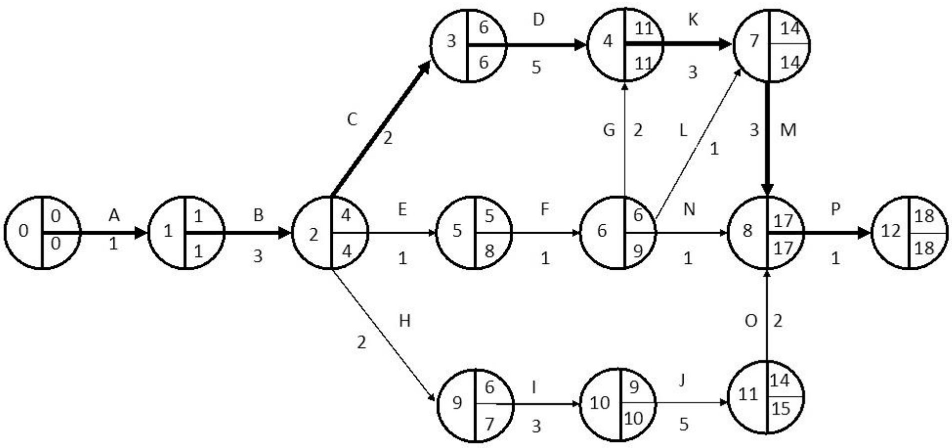

Figure 4. Network Diagram with Forward and Backward Calculations

Based on the network diagram above, the project has a critical path duration of 18 days. However, it is expected to be completed in 25 days, based on the company's experience, which shows that the longest time they have historically used is 36 days. This network, therefore, enables a time saving of 18 days.

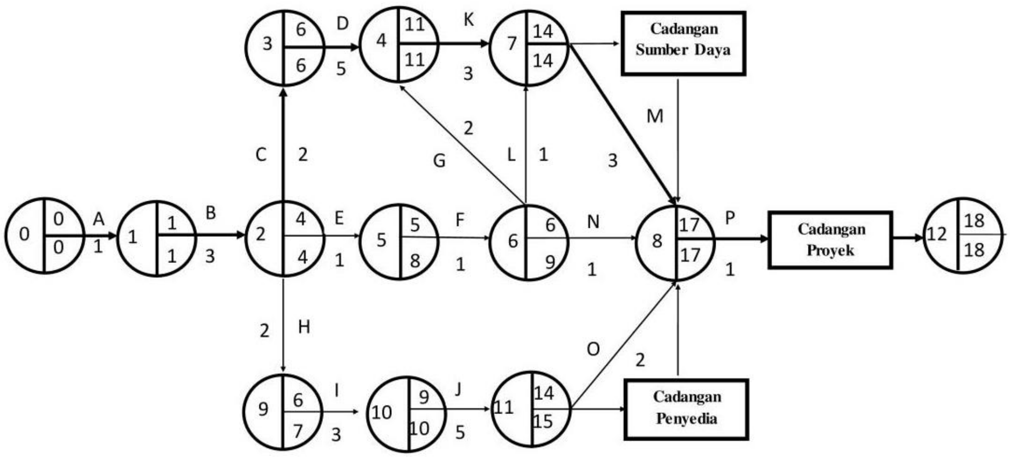

Figure 5. Network with 3 buffers

4.1 CCPM Calculation

In the Critical Chain method, buffers from each activity located on the critical path are aggregated and summed at the end, termed the Project Buffer. For activities that are not on the critical path, the buffers are consolidated at the point where these activities intersect with the critical chain, referred to as Feeding Buffers. Similarly, Resource Buffers are employed when there is limited resource availability. The provision of these three types of buffers is intended to allow high-risk activities to utilize the available buffers, thereby ensuring the project is completed on schedule. One major cause of delays in project scheduling is the substantial addition of Safety Time. Safety Time can be reduced using the Cut and Paste Method (C&PM), which involves cutting the duration of each activity by 50%.

The decrease in the duration of each task is determined using the following percentage:

1. *Critical Chain Identification*
   Critical activities represent the minimum time required to complete the project. Therefore, any delays in activities along the critical path will extend the overall project duration.

2. *Buffer for CCPM Scheduling*

Reducing the duration of activities with this method increases the likelihood of delays. Consequently, buffers or cushion time must be implemented to maintain the schedule. Buffers are added to the project timeline where activity durations have been shortened, aiming to create a more reliable schedule. In this thesis, the Root Square Error Method (RSEM) is utilized. This approach is analogous to calculating two standard deviations by considering the CPM duration (S) and the CCPM duration (A), which is 50% of the safe estimate. The buffer size is determined by solving Equation 4.1.

$$Buffer\ Size = 2\ x\ \frac{S_1\ - {A_1}^2}{2} + \frac{S_2 - {A_2}^2}{2} +\ ...\ + \frac{S_n - {A_n}^2}{2}$$

Which :

S = Duration CPM

A = Duration CCPM

The calculation of the buffer for activity code A uses the following formula:

$$\frac{\text{Duration CPM (S) – Duration CCPM (A)}}{2} = 0{,}25$$

$$(\frac{S-A}{2})^2 = 0{,}0625$$

Tabel 2. *Buffer* calculation

No	Job	Job Code	CPM Duration (S)	CCPM Duration (A)	$\frac{S-A}{2}$ (1)	$(\frac{S-A}{2})^2$ (2)
1	Ground Working	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625
3	Structure	C	2	1	0,5	0,25
4	Wall	D	5	2,5	1,25	1,5625
5	Stone	E	1	0,5	0,25	0,0625
6	Art list	F	1	0,5	0,25	0,0625
7	Installation of Frames	G	2	1	0,5	0,25
8	Work on Beam Formwork	H	2	1	0,5	0,25
9	Work on Terrace Wall	I	3	1,5	0,75	0,5625
10	Roof	J	5	2,5	1,25	1,5625
11	Plavond	K	3	1,5	0,75	0,5625
12	Floor	L	1	0,5	0,25	0,0625
13	Painting	M	3	1,5	0,75	0,5625
14	Sanitation and Piping	N	1	0,5	0,25	0,0625
15	Electrical Installation	O	2	1	0,5	0,25
16	Finishing	P	1	0,5	0,25	0,0625

Table 2 provides data from columns (1) and (2), which will be used in subsequent calculations to determine the Feeding Buffer and Project Buffer.

1. Feeding Buffer Calculation

   In the CCPM method, several types of buffers are used, specifically the Project Buffer and the Feeding Buffer. The main distinction is that the Feeding Buffer is placed at the end of non-critical chains, whereas the Project Buffer is positioned at the end of the project. The purpose of incorporating the Feeding Buffer is to safeguard the non-critical chain from delays that could jeopardize the critical chain. Buffer sizes are calculated using the Buffer Size formula, and the results are presented in Tables 3 through 4 below:

Tabel 3. Calculation *Feeding Buffer* 1

Non Critical Way A-B-E-F-G-K-M-P						
No	**Job**	**Job Code**	**CPM Duration (S)**	**CCPM Duration (A)**	$\frac{S-A}{2}$ **(1)**	$(\frac{S-A}{2})^2$ **(2)**
1	Ground	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625
3	Stone	E	1	0,5	0,25	0,0625
4	Art list	F	1	0,5	0,25	0,0625
5	Frame Instalation	G	2	1	0,5	0,25
6	*Plavond*	K	3	1,5	0,75	0,5625
7	Painting	M	3	1,5	0,75	0,5625
8	Finishing	P	1	0,5	0,25	0,0625
	Total					2,1875
					***Feeding Buffer* (Day) =**	2,96

The calculation of Feeding Buffer (Days) in table 3 is obtained using the following formula:

$$2 \text{ x } \sqrt{2,1875} = 2,96$$

Tabel 4. Calculation *Feeding Buffer* 2

Non Critical Way A-B-E-F-L-M-P						
No	**Job**	**Job Code**	**CPM Duration (S)**	**CCPM Duration (A)**	$\frac{S-A}{2}$ **(1)**	$(\frac{S-A}{2})^2$ **(2)**
1	Ground	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625
3	Stone	E	1	0,5	0,25	0,0625
4	Art list	F	1	0,5	0,25	0,0625
5	Floor	L	1	0,5	0,25	0,0625
6	Painting	M	3	1,5	0,75	0,5625
7	Finishing	P	1	0,5	0,25	0,0625
	Total					1,4375
***Feeding Buffer* (Day) =**						2,40

The calculation of Feeding Buffer (Days) in table 4 is obtained using the following formula:

$$2 \text{ x } \sqrt{1,4375} = 2,40$$

Tabel 5. Calculation *Feeding Buffer* 3

Non Critical Way A-B-E-F-N-P						
No	**Job**	**Job Code**	**CPM Duration (S)**	**CCPM Duration (A)**	$\frac{S-A}{2}$ **(1)**	$(\frac{S-A}{2})^2$ **(2)**
1	Ground	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625
3	Stone	E	1	0,5	0,25	0,0625
4	Art List	F	1	0,5	0,25	0,0625

5	Sanitation and Piping	N	1	0,5	0,25	0,0625
6	Finisihing	P	1	0,5	0,25	0,0625
	Total					0,875
***Feeding Buffer* (Day)**						1,87

The calculation of Feeding Buffer (Days) in table 5 is obtained using the following formula:

$2 \text{ x } \sqrt{0{,}875} = 1{,}87$

Tabel 6. Calcualtion *Feeding Buffer* 4

***Non Critical Way* A-B-H-I-J-O-P**						
No	**Job**	**Job Code**	**CPM Duration (S)**	**CCPM Duration (A)**	$\frac{S-A}{2}$ **(1)**	$(\frac{S-A}{2})^2$ **(2)**
1	Ground	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625
3	Ring Beam	H	2	1	0,5	0,25
4	Terrace Roof	I	3	1,5	0,75	0,5625
5	Roof	J	5	2,5	1,25	1,5625
6	Electrical Instalation	O	2	1	0,5	0,25
7	Finishing	P	1	0,5	0,25	0,0625
	Total					3,3125
***Feeding Buffer* (Day) =**						3,64

The calculation of Feeding Buffer (Days) in table 6 is obtained using the following formula:

$2 \text{ x } \sqrt{3{,}3125} = 3{,}64$

From the results of the Feeding Buffer calculations in tables 3 to 6, the conclusions as follows:

Tabel 7. *Summary* Perhitungan *Feeding Buffer*

No	**Non Critical Way**	***Feeding Buffer* (Day)**
1	A-B-E-F-G-K-M-P	2,96
2	A-B-E-F-L-M-P	2,40
3	A-B-E-F-N-P	1,87
4	A-B-H-I-J-O-P	3,64
TOTAL		10,87

4.2 Project Buffer

Once the Feeding Buffer has been calculated, the next step is to determine the Project Buffer. This buffer is added at the project's conclusion to ensure the final completion time is protected.

Tabel 8. Calculation *Project Buffer*

***Critical Way* A-B-C-D-K-M-P**						
No	**Job**	**Job Code**	**CPM Duration (S)**	**CCPM Duration (A)**	$\frac{S-A}{2}$ **(1)**	$(\frac{S-A}{2})^2$ **(2)**
1	Ground	A	1	0,5	0,25	0,0625
2	Foundation	B	3	1,5	0,75	0,5625

3	RinG Beam	C	2	1	0,5	0,25
4	Wall	D	5	2,5	1,25	1,5625
5	*Plavond*	K	3	1,5	0,75	0,5625
6	Painting	M	3	1,5	0,75	0,5625
7	Finishing	P	1	0,5	0,25	0,0625
	Total					3,625
					***Feeding Buffer* (Day) =**	3,80

The calculation of the Feeding Buffer (days) in Table 8 is obtained using the following formula:

$$2 \text{ x } \sqrt{3{,}625} = 3{,}80$$

From the calculations in Table 8, Project Buffer of 3.80 days was determined and incorporated into the CCPM scheduling method. Consequently, the total scheduling duration using the CCPM method is 10.87 + 3.80 days, which equals 14.67 days or approximately 15 days.

4.3 Network Planning for the CCPM Method

Based on the time data and types of activities structured in the Work Breakdown Structure (WBS), the next step is to create a network diagram of interdependent activities, detailing the activities in each path. This process follows the same methodology as the Critical Path Method (CPM). After constructing the WBS, which includes information on activities such as their time, duration, and interdependencies, the subsequent step is to identify the critical path. This identification begins with a forward pass calculation, as illustrated in Figure 8 below.

The total float calculation for activity code A is determined using the following formula:
Last Finish (LF) – Early Start (ES) – Day (Duration) = 0,5 – 0 – 0,5 = 0

From the Total Float calculations in Table 8, the critical path can be identified, as it has a total float of zero. This can be explained as follows:

1. Activities with a total float of 0 are A-B-C-D-K-M-P, so the path that traverses these activities is considered critical.
2. The total project completion time for a Type 36 house, using the Network Planning scheduling method, is 9 days.

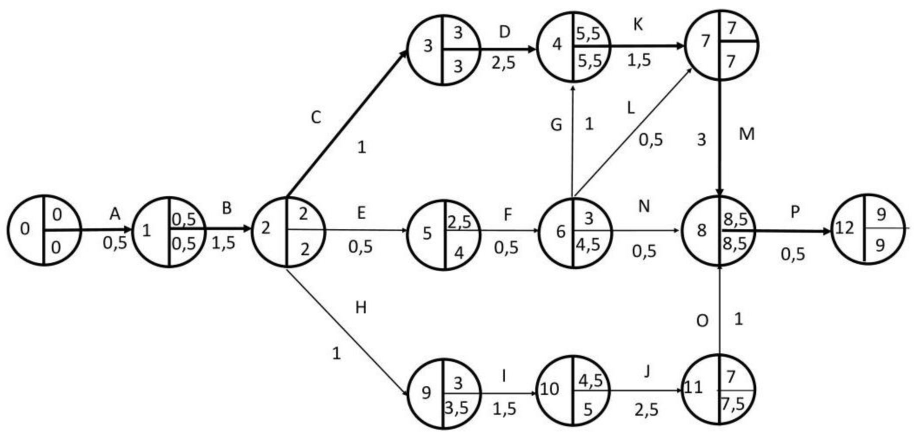

Figure 6. Forward and backward calculation diagram for CCPM

4.4 Network Planning for the CCPM Method

In the calculation of the Project Buffer, a total buffer of 15 working days and a Feeding Buffer of 11 days were obtained. The cost estimation for the buffer time (Buffer) aims to determine the potential cost savings if the buffer time is not utilized. The daily cost estimate for the buffer is calculated based on the average cost of all work per day, derived from the cost estimate (RAB). According to the daily cost recap for all tasks, the average cost from the RAB is calculated as /day. The following outlines the cost savings if the Project Buffer is not used at all.

Based on the budget calculation data in Table 8, the Critical Chain Project Management method can be calculated as follows:

1. Cost Savings from Project Buffer = average daily cost × total buffer days.
   = Rp.10.907.170,03 x 4 Day
   = Rp.43.628.680,12
2. Cost Savings from Feeding Buffer = average daily cost × total buffer days.
   = Rp.10.907.170,03 x 11 Day
   = Rp.119.978.870,33
3. Total final value = Cost Saving *Project Buffer* + *Feeding Buffer*
   = Rp.43.628.680,12 + Rp.119.978.870,33
   = Rp.163.607.550,45

The implementation also impacts cost savings, with daily costs calculated at Rp.10,907,170.03/day. Cost savings of Rp.43,628,680.12 will be realized if the 4-day Project Buffer is not consumed, and Rp.119,978,870.33 will be saved if the 11-day Feeding Buffer is not used. Consequently, the total final cost savings amount to Rp.163,607,550.45 if neither buffer is utilized. Conversely, if the buffers are consumed, an additional cost of Rp.163,607,550.45 will be incurred.

4.5 Comparison of Project Scheduling Results with CCPM Scheduling In the calculation

Using the Critical Chain Project Management (CCPM) method, the project can be completed in 15 days. The application of the Cut & Paste Method, which eliminates 50% of the safety time, results in a work duration with a 50% probability of completion without safety time. Calculations using the root square error method (RSEM) determine the size and allocation of the buffer, including the project buffer. The Feeding Buffer, amounting to 4 days, is placed between intersections with non-critical tasks leading to the critical path. Its purpose is to buffer non-critical activities from delays. The Project Buffer, total 11 working days, is positioned at the end of the critical path to protect it from delays. The integration of the project buffer and the feeding buffer results in an additional 3 working days. This implementation reduces the project completion time from 18 working days to 15 working days.

This implementation also affects the final cost, which is calculated at Rp.10,907,170.03 per day. Cost savings of Rp.43,628.680.12 will be realized if the 4-day project buffer is not consumed, and Rp.119,978.870.33 will be saved if the 11-day feeding buffer is not used. Therefore, the total final cost savings amount to Rp.163,607.550.45 if all buffers remain unused. Conversely, if the buffers are consumed, an additional cost of Rp.163,607.550.45 will be incurred. Thus, using the Critical Chain Project Management (CCPM) method can result in significant cost savings if the time buffers are not used. However, if the time buffers are used, the costs will increase in proportion to the percentage of the buffer that is utilized.

5. Conclusion

Time control for the Type 36 house construction project using the Critical Chain Project Management (CCPM) method results in a 4-day Feeding Buffer and an 11-day Project Buffer. Consequently, the project completion time is 15 days, which is 3 days faster than the original project schedule of 18 days. To avoid cost overruns for materials and labor, the Cut & Paste Method is employed to eliminate 50% of the safety time, thereby reducing the safe time to achieve a 50% probability of completion without additional safety time. Calculations using the Root Square Error Method (RSEM) determine the size and allocation of buffers, including the Project Buffer. The Project Buffer, amounting to 11 working days, is placed at the end of the critical path to protect it from delays. This approach reduces the project completion time from the original 18 working days to 15 working days. Additionally, this implementation results in cost savings, with the calculated daily cost amounting to Rp.10,907,170.03.

Limitation
This analyzing just focus on critical process but not for opportunity job can be reduce for more improvement. And for future research this method can use hybrid with another project improvement.

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References
Adibhesami, M. A., Ekhlassi, A., Mohebifar, A., & Mosadeghrad, A. M. (2019). Improving Time-Cost Balance In Critical Path Method (Cpm) Using Dragonfly Algorithm (Da). *Int. J. Ind. Eng. Prod. Res*, *30*(1), 187-194.

Anastasiu, L., Câmpian, C., & Roman, N. (2023). Boosting Construction Project Timeline: The Case Of Critical Chain Project Management (Ccpm). *Buildings*, *13*(5), 1249.

Andiyan, A., Putra, R. M., Rembulan, G. D., & Tannady, H. (2021). *Construction Project Evaluation Using Cpm-Crashing, Cpm-Pert And Ccpm For Minimize Project Delays.* Paper Presented At The Journal Of Physics: Conference Series.

Deb, D., Dey, R., & Balas, V. E. (2019). Engineering Research Methodology. *A Practical Insight For Researchers, 153*.

Fatikawati, I., Basla, L. P. S., & Safiah, S. (2022). *Optimalisasi Waktu Penjadwalan Dengan Program Evaluation And Review Technique (Pert) Untuk Pembangnan Rumah Tipe 36 Pada Pt. Arisko Di Sambutan Samarinda.* Paper Presented At The Prosiding Seminar Nasional Matematika Dan Statistika.

Fazrin, N., & Ludiya, E. (2023). Penerapan Metode Abc Dalam Perbaikan Tata Letak Gudang Bahan Baku Di Pt. Alfa Polimer Indonesia. *Studi Ilmu Manajemen Dan Organisasi*, *4*(1), 13-25. Doi:10.35912/Simo.V4i1.1049

Jo, S.-H., Lee, E.-B., & Pyo, K.-Y. (2018). Integrating A Procurement Management Process Into Critical Chain Project Management (Ccpm): A Case-Study On Oil And Gas Projects, The Piping Process. *Sustainability*, *10*(6), 1817.

Kholil, M., Alfa, B. N., & Hariadi, M. (2018). *Scheduling Of House Development Projects With Cpm And Pert Method For Time Efficiency (Case Study: House Type 36).* Paper Presented At The Iop Conference Series: Earth And Environmental Science.

Kuo, T.-C., Chang, S.-H., & Huang, S.-N. (2009). Due-Date Performance Improvement Using Toc's Aggregated Time Buffer Method At A Wafer Fabrication Factory. *Expert Systems With Applications*, *36*(2), 1783-1792.

Ma, G., Jiang, S., Zhu, T., & Jia, J. (2019). A Novel Method Of Developing Construction Projects Schedule Under Rework Scenarios. *Sustainability*, *11*(20), 5710.

Mardhiana, P., Yuliansyah, Y., Puspita, H. E., & Dewi, F. G. (2023). Analisis Pengaruh Tqm, Budaya Organisasi Serta Sistem Penghargaan Terhadap Kinerja Manajerial. *Jurnal Akuntansi, Keuangan, Dan Manajemen*, *5*(1), 1-13.

Mariana, Y., & Wijaksono, S. (2021). *Project Evaluation And Review Technique (Pert) Analysis In The Renovation Project Of The Church Of St. John The Evangelist, Jakarta.* Paper Presented At The Iop Conference Series: Earth And Environmental Science.

Marwan, A., Anderson, G., Tamalika, T., Maryadi, D., & Ardaysi, M. (2024). Optimasi Waktu Pelaksanaan Pada Manajemen Proyek Pembangunan Gedung Poltekkes Jurusan Farmasi Tahap 1 Dengan Metode Cpm Dan Pert. *Jietri: Journal Of Industrial Engineering Tridinanti*, *2*(01), 21-26.

Maryadi, D., Tamalika, T., Ardaysi, M., Hermanto, M., & Azhari, A. (2023). Improvement Performa Gudang Medium Mile Dengan Menggunakan Value Stream Mapping Case Study: Warehouse Medium Mile Di Kota Palembang. *Jurnal Ilmiah Manajemen, Bisnis Dan Kewirausahaan*, *3*(1), 40-48.

Maryadi, D., Tamalika, T., Hermanto, M., & Wongiawan, F. (2023). Analisa Kelayakan Bisnis Plts Untuk Rumah Subsidi Tipe 36 (Studi Kasus Di Kota Palembang). *Jietri: Journal Of Industrial Engineering Tridinanti*, *1*(01), 06-11.

Mediaty, M., Usman, A., Mawa'pangraran, F., Nadhifa, N., & Irianto, L. W. B. (2024). Analisis Kinerja Pt. Semen Tonasa Melalui Pendekatan Balanced Scorecard: Upaya Meningkatkan Daya Saing Di Industri Semen. *Jurnal Akuntansi, Keuangan, Dan Manajemen, 5*(3), 193-205.

Naidu, T. T. K., & Angadi, R. U. (2018). Comparative Analysis Between Critical Path Method And Monte Carlo Simulation. *International Research Journal Of Engineering And Technology (Irjet), 5*(06).

Nurhidayati, R., Falani, I., Ruchianto, A. M. A., Naufal, M., Azizah, T. N., & Praniasty, V. N. (2021). Minimasi Biaya Distribusi Makanan Ringan Pada Ukm Marcuy Dengan Metode Stepping Stone, Least Coast, Vam Dan Modi. *Studi Ilmu Manajemen Dan Organisasi*, *2*(2), 167-181.

Rakasyiwi, G. R., Witjaksana, B., & Tjendani, H. T. (2022). Project Scheduling Analysis Using The Critical Path Method–Case Study: Subsidized House Construction Project In Hill Mulya Housing, Samarinda City. *International Journal On Advanced Technology, Engineering, And Information System*, *1*(4), 73-88.

Rozi, Y. F., Aslami, N., & Dharma, B. (2024). Analysis Of Demand Volume, Material Supply, And Work Hours Against Delta Power Listrindo Cv Production Performance. *Jurnal Akuntansi, Keuangan, Dan Manajemen, 5*(3), 279-285.

Sinaga, T., & Husin, A. E. (2021a). Analysis Of Time Efficiency With Ccpm Method And Bim In Construction Projects Construction Of High-Rise Residential Building Basement. *Civil Engineering And Architecture, 9*(5), 1465-1477.

Sinaga, T., & Husin, A. E. (2021b). Key Success Factors For Critical Chain Project Management (Ccpm) And 4d Building Information Modeling (Bim) For Improving Time Performance In Basement Work On 5 Layers Of High-Rise Residential Buildings In Indonesia. *Int. J. Eng. Res. Adv. Technol., 7*(04), 22-33.

Taghipour, M., Seraj, F., Amin, M., & Changiz, D. (2020). Evaluating Ccpm Method Versus Cpm In Multiple Petrochemical Projects. *Management, 3*(3), 1-20.

Tamalika, T., & Fuad, I. S. (2022). Analisis Penjadwalan Waktu Pekerjaan Proyek Poltekkes Jurusan Farmasi Tahap I Dalam Perspektif Manajemen Proyek. *Jurnal Pendidikan Tambusai, 6*(1), 8207-8214.

Tamalika, T., Maryadi, D., Hermanto, M., Fuad, I. S., & Alamsyah, M. N. (2022). *Analisis Penjadwalan Ulang Proyek Power House Pada Rumah Sakit Dengan Metoda Pert, Cpm Dan Fishbone Diagram (Studi Kasus Pada Kontraktor Di Kota Palembang).* Paper Presented At The Prosiding Seminar Nasional Mercu Buana Conference On Industrial Engineering.

Wang, A., Chan, E., & Yeung, S. (2017). A Framework For Conservation Construction Plan Model (Ccpm). *Procedia Engineering, 196*, 816-821.

Yuliarty, P., Novia, N., & Anggraini, R. (2021). Construction Service Project Scheduling Analysis Using Critical Path Method (Cpm), Project Evaluation And Review Technique (Pert). *International Journal Of Innovative Science And Research Technology, 6*(2), 2019-2022.