



## Optimization of execution time for second-floor house extension using the critical path method (cpm)

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### ABSTRACT

A This study discusses the application of the Critical Path Method (CPM) to optimize the execution time of a two-story house extension project. Through network analysis, CPM helps identify the critical path and determine which activities must be prioritized to ensure the project is completed on time. The analysis results show that the project duration can be shortened to 41 days by effectively managing critical activities and utilizing float time optimally. Therefore, CPM has proven to be an effective tool in improving the scheduling efficiency of construction projects.

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## INTRODUCTION

Indonesia as a developing country with rapid population growth, has experienced a significant increase in the need for housing. This makes the demand for residential houses in Indonesia very high (Wardani, Musdalifah, and Lusiyananti 2018). Increasing the number of floors in a house can be an alternative infrastructure solution to overcome land limitations, especially in urban areas (Sutarto and Jalil 2023).

Based on demographic data, with a population of around 241 million and a growth of 1.3% per year, Indonesia needs around 729 thousand new housing units each year. Of the approximately 49.3 million existing housing units, about 1.48 million are damaged and in need of repair (Kusumastuti 2015).

Due to land limitations, additional floors are a realistic alternative. The addition of a second floor to a residential house is not just about adding space, but also requires careful planning so that the building structure remains safe, comfortable, and in accordance with technical standards. This concept needs to consider the efficiency of implementation time and budget management. This is where the importance of good project management, which organizes the course of the project from start to finish (Lokas, Dundu, and Pratas 2022).

However, there are still many floor addition processes that are carried out without clear project planning, such as cost overruns and delays in implementation time. In the implementation

process, there is often a difference between the previously designed schedule and the reality in the field (Lokas, Dundu, and Pratas 2022).

Delays in the construction of the second floor of a house due to inefficient planning can pose serious structural and functional risks. Structurally, lack of planning can lead to mismatched work sequences, cost overruns, and disruption to building stability, potentially reducing the strength of the construction needed to support additional loads. While functionally, project delays result in additional space not being able to be used as needed, and have an impact on the comfort and efficiency of the overall space (Yang 2021).

This is further exacerbated when project management does not utilize scheduling methods such as the Critical Path Method (CPM) which can actually help determine the most crucial work sequence and estimate the implementation time accurately. Without the application of systematic methods such as CPM, projects are vulnerable to delays, budget inefficiencies, and failure to achieve technical and aesthetic building standards.

Therefore, a systematic planning method is needed to control the project more effectively. One method that can be used is the Critical Path Method (CPM). This method helps determine the most important sequence of work in the project, so that it can be seen which activities are prioritized and can estimate the project time to be more efficient (Jouda dan Shiker 2024).

CPM is basically a project management method that focuses on the time aspect, with the main objective of determining the duration of project completion. This method identifies the critical path of a series of interdependent activities. The critical path itself refers to the sequence of activities that affect the total project completion time as a whole (Plebankiewicz, Zima, dan Wieczorek 2021).

(Iwawo, Tjakra, and Pratas 2016) argued that the CPM method has advantages in formulating, scheduling, and managing various project activities as a whole. The advantage lies in its ability to produce a schedule that is compiled based on field experience, thereby increasing the accuracy of the estimated implementation time. Therefore, CPM is able to provide a systematic and reliable planning arrangement.

However, the application of CPM is still dominated in large projects, while its implementation in small to medium construction projects such as the addition of residential floors has not been studied in depth. In fact, small-scale projects are prone to delays and cost overruns, so project scheduling is important to ensure the right sequence of work and realistic time estimates. CPM can be determined precisely from the beginning for each activity in the project (Iwawo, Tjakra, and Pratas 2016).

The application method (CPM) has quite a striking difference between residential projects and commercial projects, especially in terms of the scale of work, the amount of resources, and the approach to project management. In housing projects such as in this study, CPM is applied to the addition of the second floor to residential houses with limited work teams and simpler planning Irwanto dkk. (2023). The project is managed directly by the homeowner alongside an executor, without involving a software-based project management system.

In contrast, commercial projects such as the construction of multi-storey shophouses or office buildings typically involve a lot of experts, subcontractors, and the use of more complex management tools. On large-scale projects, CPM is implemented in a more structured system, often combined with software such as Primavera or Microsoft Project to ensure integration between schedule, cost, and project quality.

This study emphasizes the importance of adjusting planning methods to the project context. With the conditions of a small-scale project and limited resources, the CPM approach can still be executed manually with optimal results. The analysis was carried out by compiling a working network based on direct observation, interviews with builders, and literature review. From the calculation results, it is known that the duration of the project can be reduced from the initial estimate of 56 days to 41 days by managing critical activities more efficiently.

With this approach, CPM has not only proven to be effective in large projects, but it is also very beneficial for small and medium-sized projects as long as the planning is done systematically. This study shows that the use of CPM methods adapted to field conditions can help prevent delays, speed up the implementation process, and improve overall project time efficiency.

The purpose of this study is to implement the CPM method in planning and controlling the implementation time of the second floor addition project on the house. This research also aims to assess how effective the CPM method is in helping to accelerate and streamline the implementation of construction projects. Hopefully, it can be completed on time, within budget, and meet the needs and expectations of homeowners who want to add floors to their buildings.

**Definition of Building,** In designing building structures, it is important to comply with regulations to ensure adequate construction safety and the ability to withstand various types of loads (B. Saroinsong et al. 2024) The theory of the Vitruvian Trilogy, which emerged during the peak of classical architecture, states that an ideal building must contain three main elements: function (*utilitas*), strength (*firmitas*), and beauty (*venustas*). In modern architectural practice, Vitruvius's theory remains a fundamental basis, especially as a representation of Western architecture. However, not all physical structures can be categorized as architectural works merely because they exist physically; they must meet these principles to be regarded as true architecture (Yuan et al. 2022). According to the theory (Rosita 2021), the Rapid Visual Screening (RVS) method can be applied to assess building vulnerability to earthquakes in Indonesia, provided that the assessment forms are adjusted to align with local regulations and building characteristics.

**Factors Affecting Indoor Temperature,** According to (Rumbyarso 2021) climate influences living beings, and in turn, living beings also influence the microclimate. The microclimate under tree shade is better than in open areas. Therefore, it is recommended to preserve and add vegetation in campus environments to maintain microclimate quality. (Yulistya and Roosandriantini 2021), when designing comfortable buildings, it is important to consider factors such as temperature, humidity, and airflow to create an ideal environment for occupants. By understanding and managing thermal loads effectively, we can create buildings that are not only comfortable but also energy-efficient and environmentally friendly. Furthermore, proper building design can enhance occupant productivity and health while reducing long-term operational costs. Therefore, thorough planning and appropriate material selection are essential to achieving these goals. Thus, buildings can become comfortable and healthy living spaces that provide long-term benefits to occupants and the surrounding environment.

**Structural Selection Concept,** In building planning, structural aspects are crucial to ensure that the building can safely support both vertical and horizontal loads (Heri Zulfiar 2018) Structural strength must be balanced with architectural design that considers aesthetics, function, and spatial comfort (Emka 2025), as the integration of visual and functional aspects can enhance building use efficiency. Additionally, cost management is also a vital component, where accurate initial cost estimation and strict budget control are necessary to maintain project efficiency without compromising quality (Okafor dkk. 2022)

Other studies emphasize that a combination of structural design, architectural considerations, and sound financing strategies will result in buildings that are durable, functional, aesthetically pleasing, and economically viable (Amri 2023)

**Building Construction Methods,** Building construction methods generally fall into two main approaches: Bottom-Up Method, The Bottom-Up method is a traditional approach for constructing multi-story buildings, starting from the lowest parts such as foundations and basements, then continuing upward to the roof structure (Jiang, Zheng, dan Huang 2022) The initial stage includes site preparation, soil excavation for the basement, foundation construction, followed by the sequential work on columns, beams, and floors (March 2023). The advantage of this method is lower construction costs compared to the Top-Down method; however, project

duration tends to be longer because the basement work must be completed before proceeding to the upper structure (Liew and Ting 2018)

Top-Down Method, The Top-Down method is generally used for projects on limited land or in densely built-up areas. This method has advantages especially in terms of safety and pollution control, which is very important to apply in areas with high levels of occupancy (Putri, Saefudin, and Agustina 2024). This method begins with the construction of retaining walls (such as diaphragm walls or secant piles) and deep foundations (such as bored piles, (Mundo et al. 2022). After the upper structure is formed, basement excavation is carried out gradually below the floor slab while simultaneously continuing the construction of the upper structure (Series 2015). Thus, the Top-Down method can accelerate project duration since both upper and lower structures are built in parallel, although the costs are generally higher than the Bottom-Up method due to technical complexity and the need for additional heavy equipment (Mardian, Maulana, and Asih 2022).

## RESEARCH METHOD

### Object and Place of Research

The initial stages in this study include collecting primary and secondary data. Primary data were obtained directly from the project implementation location, which includes detailed information on the type of work, planning data, and project implementation schedule. Meanwhile, secondary data includes information related to the location and time of the research implementation. The research location is in Samarinda (Victory, 2025). Furthermore, a basic graph was made, the analysis was carried out by combining the main activities using the crashing method. The duration of the house construction plan in the contract is 41 days.

### Data Collection

This study requires several instruments used in this study, namely: (1) Data is collected through observation, interviews, and literature studies. (2) Observations are carried out directly in the field to understand the house building process and record important findings (Irwanto et al. 2023). Interviews are conducted with related parties such as craftsmen and project implementers to obtain in-depth information that is not visible through observation alone just (Aprilia, Shauki, 2020). (3) Meanwhile, literature studies are used to examine theories and previous research results that are relevant to the topic, as a basis for compiling an analytical framework (Hanifah et al., 2025).

### Analysis Method

#### a. Analysis with the CPM Method,

The structure of the time planning stage using the CPM method consists of the following steps: (1) The analysis in this study uses the (CPM) method to plan and control project implementation time efficiently Qomariyah and Qomariyah and Hamzah (2013). (2) The process begins by identifying all activities in the project and their relationships, then breaking them down into small parts to make them easier to analyze. Furthermore, these activities are arranged in a work network based on a logical sequence determined through literature studies, field observations, and interviews with workers. (3) The estimated time for each activity is calculated based on daily productivity data, number of workers, and worker wage rates. With this data, the Early Event Time (EET) and Late Event Time (LET) are calculated using an algorithmic approach to determine the total duration of the project and the critical path that must not be delayed (Sofia and Putri 2021).

The calculation (EET) and (LET) in the CPM method is carried out systematically based on the work sequence and the estimated duration of each activity Nopriyanto, Wulandari, dan

Nugroho (2025). However, in the implementation in the field, there are often changes due to weather factors, material availability, or unstable labor numbers. These things cause the schedule that has been arranged to undergo a shift.

In this project, even though the time calculation is done manually and has resulted in an optimal duration, flexibility is still required. The adjustment of the implementation time is carried out based on the results of direct observation and communication with the project implementer. Thus, although the CPM method is structured in nature, its success still depends on the team's ability to dynamically adapt the schedule to field conditions.

The crashing time approach in the context of the Critical Path Method (CPM) analysis results is used as an alternative strategy to optimize project duration efficiently. After the critical path is determined through CPM, the activities on the path are identified as the main focus because these activities directly affect the total project completion time Nur Yaqin, Teki Tjendani, dan Witjaksana (2023). Furthermore, each activity is analyzed based on two main parameters, namely duration and cost, both in normal and accelerated (crashed) conditions. From here, the additional cost per unit of acceleration time is calculated, which is called the crash cost per unit of time. Activities with the lowest crash costs will be prioritized for acceleration because they are more efficient in terms of expenditure. The crashing process is carried out in stages, starting from the most efficient activity until the project duration is reduced according to the target or until the additional costs are considered no longer economical. After each crashing stage, the project schedule is updated and the critical path is reanalyzed, because the acceleration of certain activities can change the structure of the project's critical path. The results of this process are then compared with the initial schedule to evaluate the reduction in duration and additional costs incurred. With this approach, projects can be completed faster without sacrificing a systematic planning structure, and allow for more effective cost control.

## RESULTS AND DISCUSSIONS

### Overview of Project Activity Process

This study discusses the implementation of a Two-Story House Extension Project using the Critical Path Method (CPM). The project was completed within 41 days by a team consisting of seven members. Project management was carried out by Mr. Rifai, while all necessary materials such as sand, stone, cement, and wood were prepared by the project owner prior to the construction phase.

Basic information regarding work stages, activity sequences, as well as the estimated shortest and normal durations was obtained through direct interviews with the contractor responsible for project execution. Through this analysis, the critical path of the project could be identified, making it possible to determine which activities have scheduling slack and which must be prioritized to ensure the project is completed according to the targeted schedule (Wardana and Agustiar 2025).

Accelerating project implementation time, especially in activities that are on a critical track and do not have time allowance ( $total\ float = 0$ ), can pose a risk to the quality of work results. Critical activities such as structural work, electrical installation, to final finishing, require precision and proportionate implementation time. If the work time is reduced without careful planning, the potential for technical errors, uncontrolled material quality, and final results that do not meet technical standards becomes greater.

In the context of this project, although the time acceleration succeeded in shortening the duration of the project from 56 days to 41 days, the implementation of critical activities was still carried out in order and directly supervised by the field implementers. This approach is important so that time efficiency does not come at the expense of building quality. Therefore, in activities without time constraints, it is important to maintain a balance between completion targets and

technical implementation standards so that the final result remains safe, comfortable, and in accordance with the expectations of the building owner.

**Network Analysis of Normal Duration Using CPM**

The visualization of the CPM method typically uses simple symbols such as rectangles or circles to represent activities or events in a project. These symbols help to systematically illustrate the sequence and relationships between activities. Below is an illustration using a circular symbol to represent a single work activity as a basic reference for project planning and control.



Explanation:

- ES (Early Start): The earliest possible start time.
- LS (Late Start): The latest possible start time without causing delay.
- EF (Early Finish): The earliest possible finish time.
- LF (Late Finish): The latest possible finish time without causing delay.
- i: Starting point of the activity.
- j: Ending point of the activity.

In constructing the project network, each work stage is identified in detail, including the relationships between activities, the duration of each task, and the sequence of work that must be followed to achieve efficient project execution. The collected information includes estimated execution times for each planned activity. The sequence of activities in normal duration is presented in Table 1.

**Table 1.** Sequence of Normal Time Activities

No	Work item	code	Next activity	Normal (Days)	Duration
1.	Preparation Work	A	-	4	
2.	Wall & Floor Installation	B	A	9	
3.	Roofing Work	C	B	2	
4.	Ceiling Work	D	C	5	
5.	Electrical Work	And	C	6	
6.	Sanitary Work	F	And	6	
7.	Painting Work	G	B, D	13	
8.	Finishing	H	G	1	

Source: (Wardana and Agustiar, 2025)

**Work Network with Normal Duration Using CPM**

According to the data in Table 1.1, each activity is represented by a specific letter symbol, indicating the sequence of work and its relationship to subsequent activities, as well as the time required for completion. The diagram below illustrates the work network constructed based on the information from the table.

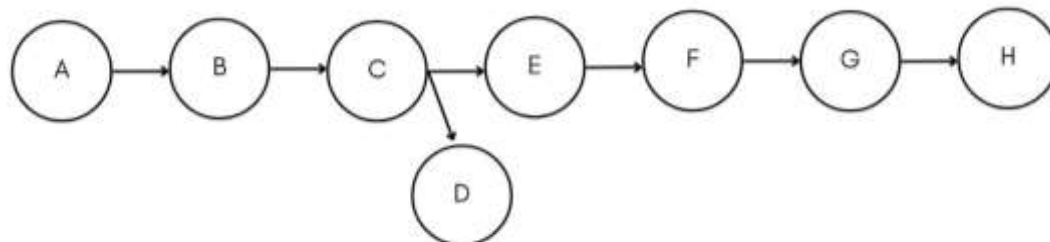


Figure 1 Work Network Diagram

Identification of the critical path A-B-C-E-F-G-H in a two-story house construction project has a significant managerial impact, especially in terms of field supervision and resource allocation. Since activities on the critical path have no time slack (total float = 0), any delay, no matter how small, will directly affect the overall duration of the project. Therefore, these activities must be the top priority in project supervision and control. Field supervisors need to pay special attention to the implementation of critical activities, ensuring that each job is carried out according to schedule without any obstacles. In terms of resource allocation, the available labor, materials, and tools must be focused first on critical path activities to avoid conflicts or delays. In addition, the activity schedule must be arranged strictly and realistically, with periodic supervision using project management tools such as CPM diagrams or software such as Microsoft Project. Coordination between workers also needs to be improved so that the transition from one activity to the next runs smoothly. To anticipate risks, contingency strategies also need to be prepared, such as the procurement of additional energy or alternative material supplies. With this approach, project management can ensure that the construction implementation is efficient and the target completion in 46 days can be achieved according to plan.

### Determining the Critical Path

After the work network is constructed, the next step is to determine the critical path by calculating the earliest start and finish times (ES and EF) through a forward pass calculation, then calculating the latest start and finish times (LS and LF) through a backward pass calculation. Next, the slack or float values are calculated to identify the critical path in the project.

**Table 2** Calculation of Activity Time and Float

No	Code	Duration (Days)	Forward Calculation		Backward Calculation		Float	Description
			IS	EF	LS	LF	TF	
1.	A	4	0	4	0	4	0	Critical
2.	B	9	4	13	4	13	0	Critical
3.	C	2	13	15	13	15	0	Critical
4.	D	5	15	20	10	15	5	Non Critical
5.	And	6	15	21	15	21	0	Critical
6.	F	6	21	27	21	27	0	Critical
7.	G	13	27	40	27	40	0	Critical
8.	H	1	40	41	40	41	0	Critical

From the table above, the float values are very important to identify which activities belong to the critical path. Furthermore, the visualization of the forward and backward time calculations can be clearly seen in Figure 1.2 below, which illustrates the forward-backward calculation network based on the data from Table 1.2.

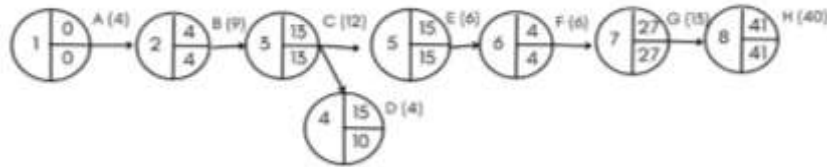


Figure 2 Forward-Backward Calculation Network

After the critical path is determined and the forward and backward calculations are obtained, the next step is to calculate the total float using the following formula: Total Float Formula = LF - EF or LS - ES. The results of the total float calculation for each activity are as follows: TF (A) = 4 - 4 = 0 (Critical) TF (B) = 13 - 13 = 0 (Critical) TF (C) = 15 - 15 = 0 (Critical) TF (D) = 20 - 15 = 5 (Non-Critical) TF (E) = 21 - 21 = 0 (Critical) TF (F) = 27 - 27 = 0 (Critical) TF (G) = 40 - 40 = 0 (Critical) TF (H) = 41 - 41 = 0 (Critical).

The forward and backward calculation data used to compute the total float are then systematically arranged to form the critical path network. The visualization of this critical path network can be seen in the following figure, which serves as an important tool in managing and controlling the project schedule.

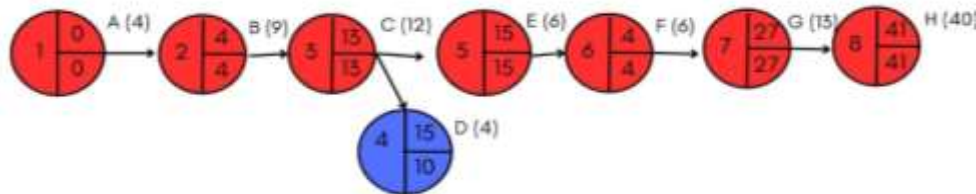


Figure 3 Critical Network

Based on Figure 1.3, the critical path in the construction project can be identified as consisting of the following activities: A (preparation work), B (wall and floor masonry work), C (roof work), E (electrical work), F (sanitary work), G (painting work), and H (finishing). The total time required to complete the project is 41 days, which is obtained by summing the duration of each activity on the critical path, namely 4 + 9 + 2 + 5 + 6 + 6 + 13 + 1 days.

## CONCLUSION

The project of adding a 2-storey house was analyzed using the (CPM) method to identify the critical path and evaluate the efficiency of the implementation schedule. Based on the initial estimate using manual calculations in Excel, the project duration was estimated to be 56 days. However, after analyzing using CPM, the project can be completed in 41 days through scheduling optimization and monitoring of critical activities. Activities included in the critical path are: - A (Preparation) - B (Wall & Floor Installation) - C (Roof) - E (Electrical) - F (Sanitary) - G (Painting) - H (Finishing). This analysis is very important to know activities with a total float of more than 0 have time leeway so that they can be postponed without affecting the total duration of the project. Conversely, activities with a total float of 0 are on the critical path and must be carried out on time so that the project does not experience delays. This study shows that the CPM method can be effectively applied to small-scale projects with a manual approach. However, going forward, this method has the opportunity to be further developed through integration with project management software such as Microsoft Project or Primavera. The use of such software can make it easier to monitor project activities in real-time and minimize time and critical path miscalculations. In addition, the integration of CPM with risk simulation methods such as Monte Carlo is also an important development potential. With this

approach, time planning is not only deterministic, but also takes into account variations and uncertainties that may occur in the field, such as weather or labor availability. This simulation can provide a more realistic estimate of the duration of the project and the level of risk. This kind of development will improve planning accuracy and decision-making flexibility, especially in construction projects that face the dynamics of field conditions.

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