Enrichment: Journal of Management, 15 (2) (2025)

Published by: Instiute of Computer Science (IOCS)

Enrichment: Journal of Management

Journal homepage: www.enrichment.iocspublisher.org

Application of project management using the critical path method (CPM) in residential construction projects

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ARTICLE INFO

Article history:

Received May 28, 2025
Revised Jun 09, 2025
Accepted Jun 16, 2025

Keywords:

Critical path method;
Management;
Project management;
Schedule;
Time Efficiency.

ABSTRACT

This study aims to analyze the application of the CPM in residential construction project in Samarinda City, in order to optimize the efficiency of implementation time. The approach used was descriptive quantitative, with data collection through field studies, documentation, and interviews. The CPM was applied by identifying all project activities, compiling a work network diagram, backward pass, and determining the earliest and latest possible start and finish times. The results showed that the project critical path had a total duration of 77 days. Delays in any of the activities on this path will have a direct impact on the overall project delay. Conversely, activities outside the critical path have time slack. These findings show that the CPM method is effective in assisting systematic and data-driven project planning and control, and makes a real contribution to improving time efficiency in the residential construction sector.

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INTRODUCTION

In recent decades, Indonesia has experienced a rapid rate of urbanization, which is characterized by an increase in the number of people migrating from rural to urban areas (Pida et al., 2025). According to the Central Statistics Agency, 56.7% of Indonesia's population resided in urban areas as of 2020. This percentage continues to increase to 60% in 2025. Correspondingly, the World Bank projects that by 2045, around 220 million Indonesians will be residing in urban areas, representing approximately 70% of the nation's total population.

Construction delays represent a global challenge. In the Indonesian context, these delays have become a persistent issue affecting most construction undertakings. During project execution, numerous disruptions tend to hinder the workflow. These obstacles cause delays in project implementation, so that the project does not take place as planned (Maddeppungeng et al., 2020). One concrete example that reflects these challenges is a residential construction project. This project shows a number of typical problems such as a mismatch between planning time and

realization in the field, dependencies between jobs that are not well managed, and not optimal use of analytical and predictive project management tools.

Such problems not only result in delays in project completion time, but also have a domino effect on cost, quality, and owner satisfaction. Delays in housing projects, for example, can cause financial losses, lower consumer confidence, and disrupt the overall construction supply chain. In addition, on a macro scale, the accumulation of inefficiencies in construction projects can reduce the competitiveness of the national construction sector amid increasingly fierce global competition. Therefore, there is a need for a project management approach that is not only practical, but also based on scientific methodologies that are proven to improve efficiency.

Effective project management planning requires careful planning so that it can be realized as expected. One important aspect of project implementation planning is the determination of the schedule of activities. All activities and the duration of each activity will be thoroughly planned in a schedule, making it possible to estimate when the project will be completed and ready for implementation. In completing a project, one method that can be used is the Critical Path Method (Huda & Prasinta, 2024a). The CPM is the longest-duration path through a project network, which dictates the earliest time the project can be completed (Saputro et al., 2023). Therefore, the critical path includes a continuous series of critical tasks, spanning from the project's first to last activity. This path holds significant importance for project execution, as delays in any of its activities will affect the completion time of the entire project (Saputro et al., 2023).

The urgency of this research lies in the need to strengthen the project management system based on quantitative and systematic methods in residential construction projects, especially in developing urban areas such as Samarinda. Project management is essential for coordinating all phases of a project, from the start through to its final stage (Perdana & Sari, 2022). Project management involves the processes of planning, leading, organizing, and managing organizational resources to accomplish specific objectives within a defined timeframe (Perdana & Sari, 2022). By utilizing the CPM, the entire set of activities in the project can be modeled in the form of a network diagram. Through the network, the sequence of activity stages, activities that run parallel, and interprocess linkages can be identified. In addition, the duration of the entire project can also be estimated based on the series of stages that have been planned (S. M. Siagian, 2021). One of the advantages of the CPM is that the critical path in the construction process will help management to stay on top of the task ahead and thus prevent delays in all activities along the path. CPM has several drawbacks, such as increased complexity in managing large projects, lack of provisions for staff scheduling, ambiguity in identifying the critical path that demands precise calculation, and difficulties in accurately estimating the time needed to complete tasks (Alan Muin, 2022).

CPM has long been used as an effective project scheduling method in identifying critical activities that determine the minimum project duration. Many previous studies have shown that the application of CPM can help manage project time efficiently, especially in the construction and civil engineering sectors (Chasan et al., 2022; Yudy, 2016). Research by M. D. Siagian et al. (2019) emphasizes the necessity of recognizing the critical path, as delays in the execution of its activities directly contribute to the postponement of the whole project. Meanwhile, Huda & Prasinta (2024b) revealed that the CPM method is very useful to determine the optimal time for project work and monitor project progress continuously.

The focus of this research is on the application of the CPM method in a residential construction project in Samarinda, which includes identification of all project activities, preparation

of work network diagrams, determination of the critical path, and analysis of the efficiency of project implementation time. Through this approach, the research aims to provide an empirical picture of how CPM can be applied in the context of medium-scale housing projects and contribute to the improvement of planning and time control of construction projects. With this in mind, this study aims to apply the CPM directly in a residential construction project in Samarinda City. This study will not only test the effectiveness of CPM in improving time efficiency, but also fill the gap in the literature related to the application of this method in house construction projects.

The management of construction projects entails coordinating the planning, organizing, directing, and controlling of resources to meet project objectives efficiently. This includes managing time, cost, labor, technology, and materials in a series of structured activities (Surahman et al., 2024). This system is designed to align all project elements in a logical workflow to ensure successful implementation (Riga Ari Nurgani et al., 2024).

The CPM is a tool in planning and controlling project time and costs with the aim of minimizing duration and expenses (Riga Ari Nurgani et al., 2024). According to Adedeji and Bello cited by Ilwaru et al. (2018) CPM is very suitable for use in scheduling and managing construction activities because it is based on experience and field observations, here is an example of a CPM display for each activity and its symbols.

According to Ramadhani et al. (2024), the critical path calculation in project management involves two main steps: the forward pass and the backward pass. In the forward pass, the Earliest Event Time (EET) is calculated using the formula EET_j = max (EET_i + D_{ij}), starting from the initial node where EET = 0. Then, the backward pass is performed to determine the Latest Event Time (LET) using the formula LET_i = min (LET_j - D_{ij}), starting from the end node with the condition that EET_n = LET_n. An activity (i, j) is considered part of the critical path if it meets two conditions: EET_i = LET_i and EET_j = LET_j, indicating that the earliest and latest times are equal, and EET_j - EET_i = D_{ij}, meaning that the time difference between events matches the duration of the activity.

CPM helps establish a structured workflow in construction projects, including the establishment of realistic schedules, allocation of labor resources, materials, equipment, and time-cost control to prevent plan deviations, Identification of critical activities allows contractors to prioritize tasks that affect project duration (Nugroho & Marbun, 2024). CPM is used to organize the stages of preparatory work, structure, finishing and optimize resource allocation. Identification of critical activities such as foundations helps reduce the risk of delays and cost wastage.

Time efficiency in residential construction projects is a vital element that directly affects the overall success of project implementation. Inaccuracies in time management can have serious consequences, both financially and operationally, such as increased implementation costs due to the use of additional resources, disruption to other project schedules, and potential penalties for delays. In addition, delays also have an impact on non-technical aspects, such as decreased customer satisfaction levels, disruption of contractor cash flow, and reduced trust in the developer. Therefore, time is one dimension that is very important to be carefully controlled through a measured and systematic approach.

CPM offers a relevant quantitative solution to efficiently design project schedules and identify critical activities that have a direct influence on the total project duration. The application

of CPM allows project managers to develop a logical sequence of work, allocate resources optimally, and minimize the risk of delays through monitoring activities on the critical path. By placing time efficiency as the main focus, this research seeks to demonstrate the real contribution of CPM in improving schedule management on medium-scale construction projects, particularly on housing projects in developing urban areas such as Samarinda City.

RESEARCH METHOD

The research method applied by the author is descriptive quantitative, focusing on the analysis of CPM usage in a residential construction project located in Samarinda starting from February 2025. Based to Sugiyono (2013), quantitative methods rely on the philosophy of positivism, involving the investigation of certain populations or samples, data collection through research instruments, and performing statistical analyses with the purpose of testing hypotheses set in advance. Descriptive research, as explained by Arikunto (2010) seeks to investigate situations or various phenomena (such as the environment, conditions, or events), with outcomes documented in a formal research report. The project management control method used is using CPM.

The descriptive quantitative approach was chosen because it is able to provide a comprehensive and measurable picture of project implementation in the field. According to (Creswell, 2014), this approach is suitable when researchers want to analyze the relationship between variables using numerical data. Meanwhile, the descriptive approach allows researchers to explain the context of project implementation in depth and factually. CPM supports effective and efficient project analysis, planning, and scheduling by identifying the critical path and activities that directly influence the overall timeline (Sinurat & Misdalena, 2024).

To ensure the accuracy of the duration estimation of each activity in the project work network, this research utilizes a data triangulation approach through the incorporation of technical inputs from the field, historical data of similar projects, and available project planning documents. Time estimates for each job were not only sourced from planning schedules on paper, but also reviewed based on the practical experience of professionals directly involved in the implementation of residential construction projects, so that the time figures used in the critical path analysis reflect operational realities in the field and are not merely the result of theoretical assumptions.

With CPM, the activity paths that most affect project duration can be optimally monitored and controlled. Data can be collected through various settings, sources, and approaches depending on the needs of the research. According to Danuri et al. (2019) when viewed from the perspective of data sources, data collection may involve both primary and secondary data. The integration of primary and secondary data was done systematically to strengthen the validity of the CPM model. Primary data was obtained through direct interviews with project implementers as well as observations of construction activities at the site, while secondary data included technical documents such as the Cost Budget Plan, S-curves, and a list of activity sequences in the project implementation plan. In conducting this research, a direct interview method was used to obtain primary data and request project data from the authority working on a residential construction project to obtain secondary data. Both types of data were then analyzed simultaneously to ensure alignment between the actual conditions in the field and the project plan that had been prepared previously. This process enables the development of a work network that is not only calculatively

accurate, but also contextual, so as to realistically describe the relationship between activities and support a comprehensive analysis of project implementation time efficiency.

RESULTS AND DISCUSSIONS

Project Planning Analysis with CPM

At this stage, the researcher compiled a house construction project planning using the CPM. According to Rembulan & Yuhao (2023) CPM operates as an adaptable system that evolves with ongoing project progress. This approach applies a single time estimation technique, where time is treated as a fixed value. In project management, the Critical Path Method is a fundamental and essential tool, focusing on the sequence of terminal elements within the project network. The core of this method lies in identifying each path made up of project activities and determining the critical path among them.

Within project management, drafting a network plan primarily aims to determine critical paths in an extensive network, prioritize essential resources, optimize project potential, and apply corrective actions to minimize the overall time required. As described by Khotimah et al. (2024) the critical path is a set of interdependent activities, activities that must be completed according to the planned time because otherwise the overall project work time will be delayed. The preparation is carried out by identifying all work activities based on data, then mapping the dependency relationship between activities, the duration of each job, and compiled in the form of an activity table. After the preparation of the table, continued with the creation of a network diagram and the calculation of the Early Start (ES), Early Finish (EF), Late Start (LS) and Late Finish (LF) times, the CPM has a pseudo work item (Fahrian et al., 2022).

Planned Project Activities

The following is the preparation of the Project Activity Table using the CPM.

Table 1. Planned Activities

Name	Duration (day)	Start Date	Finish Date	Predecessor
Preparatory Workers	3	01/05/2025	03/05/2025	-
Cleaning Work	2	04/05/2025	05/05/2025	A
Foundation Excavation Work	3	06/05/2025	08/05/2025	B
Stone foundation masonry work	3	09/05/2025	11/05/2025	C
Sloof Work	4	12/05/2025	15/05/2025	D
Brickwork	6	16/05/2025	21/05/2025	E
Practical Column Work	3	22/05/2025	24/05/2025	F
Ring Balk Work	3	25/05/2025	27/05/2025	G
Roof Horses Work	4	28/05/2025	31/05/2025	H
Roof Covering Work	2	01/06/2025	02/06/2025	I
Wall plastering work	5	03/06/2025	11/06/2025	J
Ceramic Floor Work	4	08/06/2025	11/06/2025	K
Wall painting work	3	12/06/2025	14/06/2025	L
Ceiling Work	2	15/06/2025	16/06/2025	L
Electrical installation work	3	17/06/2025	19/06/2025	K
Sanitation Work	2	20/06/2025	21/06/2025	K
Final Cleaning	1	22/06/2025	22/06/2025	M, N, O

The table displays a list of project activities that include the name of the activity, the length of work in days, the Start Date, the Finish Date, and the dependency relationship between activities (Predecessor). This information is the basis for creating a critical path diagram that is useful for

project planning and management. The data enables an assessment to recognize the critical path and measure the slack time of each project activity.

Critical Path Calculation Results

The following is the preparation of the project trajectory using the CPM.

Table 2. Quick Time Activation

Code	Activity	Duration (day)	Predecessor
A	Land Clearing	3	-
B	Bouplank Installation	3	A
C	Provision of Working Water	1	A
D	Excavation of Foundation Soil	3	B, C
E	Backfill	2	E
F	Empty stone masonry	3	E
G	Cast Concrete Sloof	4	G
H	Roof Work	3	H
I	Window & Frame Work	4	H
J	Finishing (Paint, etc.)	5	I
K	Septitank & Infiltration Work	6	G
L	Back Cleaning	2	K, J

From the calculation results, the activity trajectories that form the critical path of the project are obtained, namely:

$$A \rightarrow B \rightarrow E \rightarrow F \rightarrow I \rightarrow J \rightarrow K \rightarrow L \rightarrow M \rightarrow S \rightarrow T \rightarrow U \rightarrow V \rightarrow W \rightarrow X \rightarrow AD \rightarrow AF$$

The total duration on the critical path is 77 days. This means that if there is a delay in one of the activities on this path, the overall project will be delayed. Meanwhile, activities outside the critical path have slack or time allowances that allow work to be done not on time without disrupting the overall project schedule. This finding supports the results of the study Anggraini et al. (2025) which showed that CPM can be effectively used in scheduling housing projects and assist contractors in accurately mapping the project completion time. This is in accordance with the time-cost trade off concept discussed Aprillia et al. (2023), that project speeding-up measures should prioritize activities that have a substantial impact on the final completion timeline.

Visual Interpretation of Critical Path

Tools like Gantt charts and the CPM are commonly utilized to visualize project schedules and facilitate easier monitoring of progress. The use of these tools assists the team in tracking progress and ensuring that no activities are missed or delayed (Pontan, 2024).

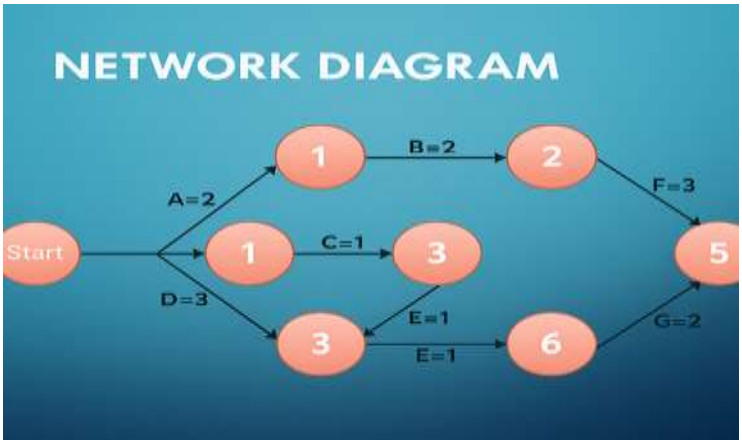

Figure 1. Network Diagram

Critical Path Backward Pass

Here is the Critical Path Backward Pass Method Diagram.

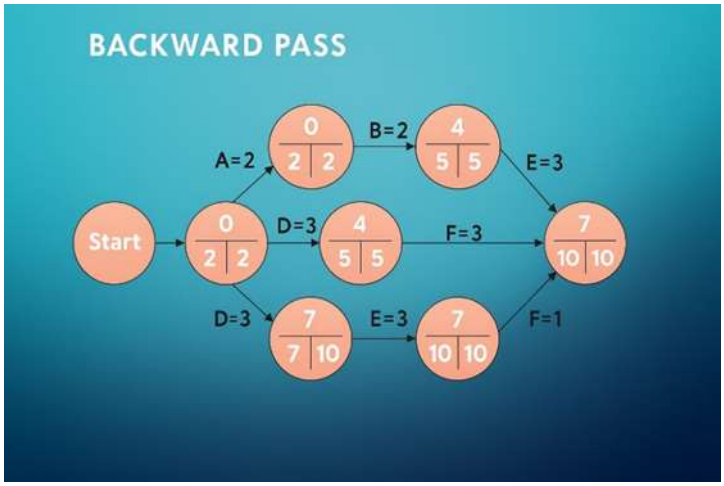

Figure 2. Backward Pass

This figure shows the backward pass calculation to determine the CPM of the project. Each node contains three numbers representing Early Start (top left), Early Finish (top right), and Duration (bottom). Through the backward pass process, Late Start and Late Finish times are derived for each task, allowing critical paths lacking slack to be recognized.

Slack on non-critical activities is strategically utilized to optimize the allocation of resources such as manpower and heavy equipment. With this free time, project managers can reorganize work schedules to be more efficient without disrupting activities on the critical path. Proper utilization of slack also helps reduce idle time in resource use, improve equipment efficiency, and maintain smooth distribution of work in the field.

However, if non-critical activities are not properly monitored, potential delays can accumulate until they approach the critical path. This can impact the accuracy of the CPM model and disrupt the estimated project completion. Therefore, thorough monitoring of all activities,

including those outside the critical path, is essential to maintain schedule consistency and overall project time control effectiveness.

CONCLUSION

This research demonstrates that implementing the CPM can significantly enhance the efficiency of planning and time management in a residential construction project in Samarinda City. By identifying all project activities, preparing a network diagram, and calculating the implementation time of each activity, a critical path with a duration of 77 days was obtained as the main reference for project completion. These results demonstrate that any postponement in critical path activities will impact the entire project timeline, while tasks outside the critical path possess available slack time. Thus, CPM not only helps minimize the risk of delays, but also provides a strong foundation in making data-based managerial decisions to improve the effectiveness and efficiency of project implementation.

The implications of these findings support the development of standardized time management policies in the medium-scale residential construction sector in developing cities, such as the need for regulations or technical guidelines that require the use of network-based planning methods such as CPM as standard practice to improve the timeliness of project completion. As a practical recommendation, contractors and developers are advised to adopt CPM consistently, especially on projects with high complexity. CPM helps with priority activity mapping, efficient resource scheduling, and more measurable progress monitoring, thus supporting data-driven decision-making and minimizing potential delays in various project scenarios.

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