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Critical path method (CPM) for scheduling a type 36 residential house construction at Grand Permata Hijau housing, Samarinda city

Khoirur Rosidin[1], Maulana Hamdan Rifa'i[2], Deddy Pramana Zulkarnain[3], Surahman[4], Tandi Kadang[5]

[1,2,3,5]Digital Business, Politeknik Negeri Samarinda, Samarinda, Indonesia

[4]Marketing, Innovation and Technology, Politeknik Negeri Samarinda, Samarinda, Indonesia

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ABSTRACT

Small-scale residential construction projects often experience delays due to weak schedule control and unstructured scheduling. This study aims to apply the Critical Path Method (CPM) to schedule the construction project of a Type 36 residential house at Grand Permata Hijau Housing, Samarinda City, to identify the *critical path* and determine the optimal completion duration. This research used a quantitative descriptive approach with a case study method. Project data, including the Cost Budget Plan (RAB) and initial schedule, were analyzed by constructing an *Activity on Node* (AON) network diagram, followed by *forward pass* and *backward pass* calculations. The CPM result indicates a potential reduction in project duration compared with the initial 120-calendar-day target. The resulting *critical path* consists of nine activities, including Preparation Work (A), Foundation Work (C), Concrete Work (D), Wall Masonry Work (E), Roofing Work (H), Ceiling Work (I), Wood & Frame Work (J), Painting Work (L), and Handover (O). This study proves that the CPM method is effective in optimizing scheduling time and can serve as a reference for time control in small-scale residential construction projects at the local level.

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Corresponding Author:

Khoirur Rosidin,
Digital Business,
Politeknik Negeri Samarinda,
Jalan Dr. Cipto Mangunkusumo Kampus Gunung Panjang, Samarinda, 75131, Indonesia
Email: khoirurrosidin99@gmail.com

INTRODUCTION

Construction projects, including small-scale residential construction, often experience delays due to weak schedule control, lack of coordination between activities, and inefficient allocation of project resources. Surahman, Kusumah, et al. (2024) noted that this condition is further exacerbated by the tendency of small-scale housing projects to be carried out without a structured scheduling framework, meaning potential delays cannot be identified early. In Samarinda City, the growth of housing development driven by population migration flows and the impact of the new national capital development further increases the demand for efficiency in completing housing projects, as

explained by Pida et al. (2025). This condition puts housing developers under increasing pressure to complete projects on time and within the set budget (Anggraini et al., 2025).

Project management is the art and science of leading an organization, encompassing the planning, execution, and control of limited resources to achieve predefined goals and targets. Arianie & Puspitasari (2017) explain that in the construction context, project management includes three interrelated main elements, namely time, cost, and quality, where a change in one element will directly impact the others. This is reinforced by Ningsih et al. (2025), who state that construction project failures generally stem from weak planning and schedule control, which ultimately results in delays, decreased quality, and increased costs. Therefore, Idris & Islami (2025) emphasize that the adoption of a structured scheduling method is a fundamental necessity in every construction project execution, as it directly determines the quality of time control outcomes. Project scheduling is the core of time management, which is the process of sequencing and determining the timing of activity execution based on logical relationships between activities and resource availability. According to Surahman, Saputri, et al. (2024), good scheduling must not only contain the sequence of work but also reflect the dependencies between tasks logically and realistically according to field conditions. A network diagram is a commonly used tool in project scheduling because it visually represents all activities and their dependencies. Sumbung et al. (2025) distinguish two main approaches in creating network diagrams, namely *Activity on Arrow* (AOA) and *Activity on Node* (AON), where AON is more widely used because it places activities directly on the nodes. Aprillia et al. (2023) add that accuracy in determining the logical relationships between activities in a network diagram is a primary prerequisite for the accuracy of all subsequent scheduling analyses.

The Critical Path Method (CPM) is a network-based project planning and control method used to identify the *critical path*, which is the longest sequence of activities that determines the minimum project completion duration. Surahman, Saputri, et al. (2024) explain that CPM works under the assumption that the duration of each activity is known with certainty, thus it is deterministic and suitable for construction projects with complete data availability. Unlike conventional methods such as the Gantt Chart, which only display activity schedules, Zunaidah et al. (2024) emphasize that CPM is able to explicitly display logical relationships between activities, allowing project managers to know the impact of a delay in one activity on the entire project. In applying CPM, several time terms are used, such as *Early Start* (ES) and *Early Finish* (EF) which are calculated through a *forward pass*, as well as *Late Start* (LS) and *Late Finish* (LF) which are calculated through a *backward pass*. Suramli et al. (2025) define *Total Float* (TF) as the slack time an activity has, calculated as $TF = LF - EF$ or $TF = LS - ES$. As emphasized by Mufahri & Oetomo (2023), activities with a value of $TF = 0$ *are* called *critical activities*, and this series of critical activities forms the project's *critical path*. Several studies have also demonstrated that CPM can be integrated with cost estimation techniques to simultaneously optimize both time and budget dimensions of a construction project (Husna et al., 2022). The identification of the critical path makes three concrete contributions to construction project control effectiveness (Idris & Islami, 2025). First, it enables project managers to concentrate supervisory resources on activities that directly determine project duration, rather than treating all activities with equal priority. Second, it provides a scientific basis for acceleration decisions, as managers can identify precisely where additional time or cost investment will have a direct impact on project completion. Third, early identification of the critical path allows potential delays to be detected before they occur, enabling corrective action to be taken proactively rather than reactively.

Various studies have proven the effectiveness of CPM across different construction project types. The first group covers Samarinda-based projects, including shophouse construction (Surahman, Kusumah, et al., 2024), housing in Selili District (Surahman, Saputri, et al., 2024), boarding house projects (Suramli et al., 2024), type 78 house construction (Suramli et al., 2025), type 45 house construction (Ningsih et al., 2025), residential construction projects (Satryawati et al.,

2025), subsidized housing in Samarinda (Rakasyiwi et al., 2022b), CPM-PERT integration in Kunjang River Region (Prapdopo et al., 2024), and a CPM-based building project management analysis (Kadang et al., 2024). The second group encompasses projects outside Samarinda, including a building project in Tanjung Karang (Sinurat & Misdalena, 2024), a flood embankment project in Gresik (Qordhowi & Fendrawan, 2025), a bridge project in Kuningan (Pangestu et al., 2021), and a check dam project in Padang (Kurnaini et al., 2021). Rakasyiwi et al. (2022a) further confirmed through a systematic literature review that CPM remains the most widely applied scheduling method in Indonesian construction projects over the last five years. However, limited studies have examined actual data-based CPM scheduling for small-scale Type 36 housing projects in Samarinda, particularly in subsidized housing projects where developers must control time efficiency under limited resources. Unlike Type 45 and Type 78 housing projects that have been relatively well-studied through CPM, Type 36 housing presents a distinct challenge due to its simpler structural scope combined with tighter resource margins. The reduced number of activities does not necessarily simplify scheduling; rather, each day of delay carries proportionally greater consequences on the overall project timeline. This distinction underscores the importance of examining CPM application specifically within the context of small-scale subsidized Type 36 housing, which remains underrepresented in existing literature.

The novelty of this research lies in the systematic application of CPM to a small-scale one-story residential construction project by identifying critical activities and translating the scheduling results into practical time control recommendations that can be directly applied by project implementers. Grand Permata Hijau Housing in Samarinda City was chosen as the research object because it is an active subsidized housing project with complete and accountable data availability, making it representative as a case study of CPM application in small-type housing at the local level. This study aims to apply CPM to the scheduling of the type 36 residential construction project in Grand Permata Hijau Housing, Samarinda City, East Kalimantan, with the objectives of identifying all project activities and their interdependencies, constructing a project network diagram, determining the *critical path* and optimal project duration, and providing time control recommendations for similar projects in Samarinda City.

RESEARCH METHOD

This study uses a quantitative descriptive approach with a case study method. This approach was chosen because it aims to analyze numerical data in the form of project activity durations using the mathematical procedures of CPM to produce measurable and verifiable conclusions (Surahman, Kusumah, et al., 2024). The case study method allows for an in-depth analysis of a specific project object while considering its unique context and characteristics (Ningsih et al., 2025). The research was conducted at the construction project of a one-story type 36 residential house in Grand Permata Hijau Housing, Jl. Jayakarta RT.19, Rawa Makmur Village, Palaran District, Samarinda City, developed by PT Borneo Permata Hijau. This project is part of a subsidized housing program planned to be completed in 120 calendar days, covering work from site preparation to building handover.

Research data was sourced from official project documents in the form of the Cost Budget Plan (RAB) and work schedule data. The selection of Grand Permata Hijau Housing as the research site was based on three primary considerations. First, the project provided complete and accountable documentation in the form of an official Cost Budget Plan (RAB) and work schedule, which are essential inputs for CPM analysis. Second, the project is developed by a registered developer with clear legal standing, ensuring that the data obtained is reliable and verifiable. Third, its location in Palaran District, Samarinda, makes it geographically and contextually representative as a case study for CPM application in small-scale subsidized housing at the local level.

Data analysis was conducted using the Critical Path Method (CPM) by determining the code and duration of each project activity, constructing a network diagram based on dependency relationships (predecessors) between activities using the *Activity on Node* (AON) approach, and performing a *forward pass* calculation to determine the *Early Start* (ES) and *Early Finish* (EF). The establishment of dependency relationships between activities was grounded in two complementary sources. The first is technical construction logic, which refers to the sequential requirements inherent to building practice, such as the requirement that Foundation Work cannot commence before site preparation is complete, and that Roofing Work cannot begin until Wall Masonry Work has reached the necessary structural height. The second is direct confirmation with the project implementer from PT Borneo Permata Hijau, which ensured that the predecessor relationships used in the CPM model accurately reflected actual field conditions rather than theoretical assumptions alone. Based on these two sources, the predecessor structure used in the CPM model was finalized before proceeding to the next calculation steps. This was followed by a *backward pass* calculation to determine the *Late Start* (LS) and *Late Finish* (LF), calculating the *Total Float* (TF) using the formula $TF = LF - EF$, and finally identifying the *critical path* as a sequence of activities with $TF = 0$.

Mufahri & Oetomo (2023) emphasize that this procedure enables the quantitative identification of priority activities that cannot be obtained through conventional scheduling methods. Pratama & Lubis (2025) add that using project management software in applying CPM improves calculation accuracy and minimizes manual errors in network analysis. Therefore, the entire analysis process was carried out sequentially with the help of Microsoft Project to produce an accurate and verified network diagram (Suramli et al., 2025).

Regarding the time basis of the analysis, the analysis used a working-day calendar, while the initial project target was expressed in calendar days; therefore, the comparison between both durations is interpreted as potential time efficiency rather than a direct one-to-one equivalence.

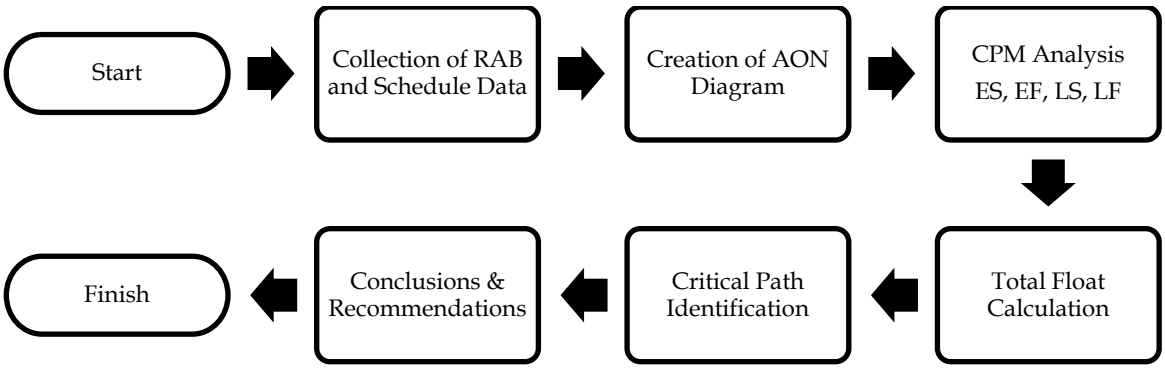


Figure 1. Research Flowchart
Source: Data processed by authors, 2026

Microsoft Project was used to visualize the AON network and verify the CPM calculation. The analysis focused only on activity duration and logical dependency relationships, without resource leveling or cost optimization.

RESULTS AND DISCUSSIONS

The type 36 residential construction project at Grand Permata Hijau Housing is part of a subsidized housing program developed by PT Borneo Permata Hijau in Palaran District, Samarinda City. The project is scheduled to be completed in 120 calendar days, covering work from land preparation to building handover. All project data used in this analysis were obtained

from official project documents in the form of the Cost Budget Plan (RAB) and work schedules. From the identification of these project documents, 14 main activity groups were obtained along with their respective durations and predecessor relationships, as presented in Table 1.

Table 1. List of Activities, Codes, Predecessors, and Durations

No	Activity Name	Code	Predecessor	Duration
1	Preparation Work	A	-	3
2	Earthwork	B	A	6
3	Foundation Work	C	A	9
4	Concrete Work	D	B, C	17
5	Wall Masonry Work	E	D	10
6	Plastering Work	F	E	11
7	Tile Installation	G	F	4
8	Roofing Work	H	E	11
9	Ceiling Work	I	H	14
10	Wood & Frame Work	J	I	9
11	Lock & Glass Work	K	J	4
12	Painting Work	L	J	14
13	Sanitation Work	M	D	6
14	Electrical Work	N	E	6
15	Project Handover	O	K, L, M, N, G	0
Linear Cumulative Duration				**124**

Source: Data processed by authors, 2026

The linear Cumulative Execution Total of 124 days listed in Table 1 is the result of a linear mathematical addition of all activity durations if the project were carried out purely sequentially (in series) without any overlapping work. This figure reflects the worst efficiency condition if the project is run without a formal scheduling management framework, which logically would exceed the original planned target limit of 120 calendar days set by the developer. Based on Table 1, several activities can run in parallel. After Preparation Work (A) is completed, Earthwork (B) and Foundation Work (C) can be done simultaneously. Furthermore, after Concrete Work (D) is completed, Wall Masonry Work (E) and Sanitary Work (M) start running in parallel. This flexibility continues after the walls are finished, where the project parallels Plastering Work (F), Roofing Work (H), and Electrical Work (N). Surahman, Kusumah, et al. (2024) explain that the existence of such parallel activities enables the optimization of the total project duration compared to conventional scheduling. Based on these data, the project network diagram was constructed using the *Activity on Node* (AON) approach.

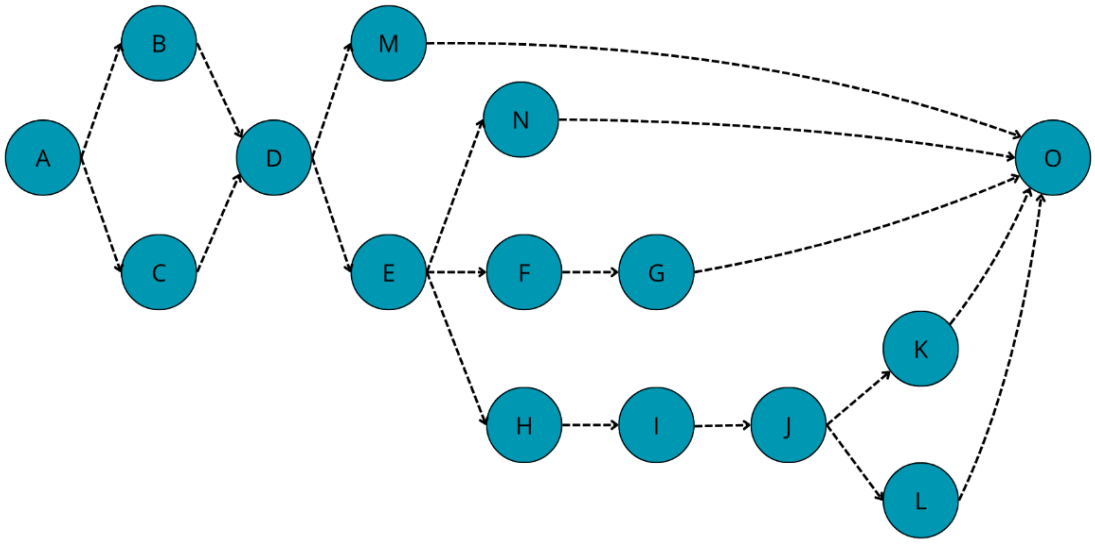


Figure 2. Work Network Diagram (*Network Diagram*)
Source: Data processed by authors, 2026

The network diagram shows the overall flow of project activities from the beginning to the Handover *milestone* (O). It can be seen that the network forms a main path starting from Preparation Work (A) and Foundation Work (C), which then branches out, where the sequence of Roofing Work (H) to Ceiling Work (I), Wood & Frame Work (J), and Painting Work (L) becomes the route that most determines the overall project duration. As stated by Sumbung et al. (2025), meeting points in such a network are nodes that require special attention in schedule control. Following the network structure, a *forward pass* calculation was performed to determine the *Early Start* (ES) and *Early Finish* (EF), followed by a *backward pass* calculation to determine the *Late Start* (LS) and *Late Finish* (LF) of each activity. The complete calculation results are presented in Table 2.

Table 2. CPM Calculation Results (*ES, EF, LS, LF, TF*)

No	Code	Activity Name	Duration	ES	EF	LS	LF	TF	Status
1	A	Preparation Work	3	0	3	0	3	0	Critical
2	B	Earthwork	6	3	9	6	12	3	Non-Critical
3	C	Foundation Work	9	3	12	3	12	0	Critical
4	D	Concrete Work	17	12	29	12	29	0	Critical
5	E	Wall Masonry Work	10	29	39	29	39	0	Critical
6	F	Plastering Work	11	39	50	72	83	33	Non-Critical
7	G	Tile Installation	4	50	54	83	87	33	Non-Critical
8	H	Roofing Work	11	39	50	39	50	0	Critical
9	I	Ceiling Work	14	50	64	50	64	0	Critical
10	J	Wood & Frame Work	9	64	73	64	73	0	Critical
11	K	Lock & Glass Work	4	73	77	83	87	10	Non-Critical
12	L	Painting Work	14	73	87	73	87	0	Critical
13	M	Sanitation Work	6	29	35	81	87	52	Non-Critical
14	N	Electrical Work	6	39	45	81	87	42	Non-Critical
15	O	Project Handover	0	87	87	87	87	0	Critical
Estimated Project Duration			87 Working Days						
Critical Path: A → C → D → E → H → I → J → L → O = 87 Working Days									

Source: Data processed by authors, 2026

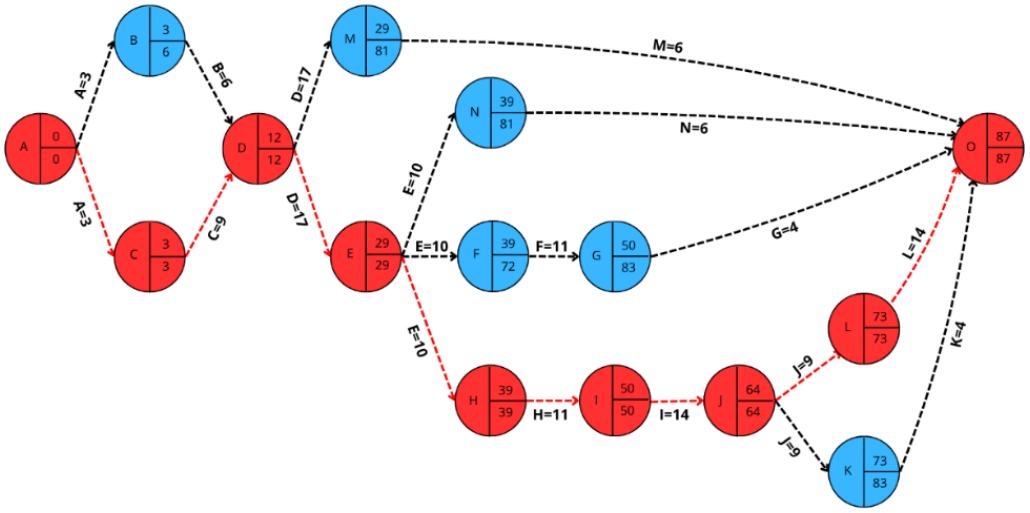


Figure 3. Forward Pass, Backward Pass, and Critical Path Diagram
Source: Data processed by authors, 2026

Based on the calculation results in Table 2, this project can be completed in an optimal duration of 87 working days. Referring to the *Total Float* formula *TF = LF - EF* or *TF = LS - ES* as applied by Surahman, Saputri, et al. (2024), the float value of each activity is calculated in detail where activities A, C, D, E, H, I, J, L, and O resulted in a value of 0 (*Critical*). Meanwhile, the other activities yielded positive float values, such as B (3 days), K (10 days), F (33 days), G (33 days), N (42 days), and M (52 days) indicating they are *non-critical*. The series of critical activities forms a single main route (*critical path*), namely **A → C → D → E → H → I → J → L → O** with a total completion duration of 87 working days. Three primary factors explain why this particular sequence constitutes the critical path. First, Foundation Work (C, 9 days) has a longer duration than Earthwork (B, 6 days), despite both beginning after Preparation Work (A) is completed, causing the critical path to pass through C rather than B. Second, after Wall Masonry Work (E) is completed, the downstream sequence through Roofing Work (H-I-J-L) accumulates a total of 48 working days, significantly exceeding the alternative paths through Plastering Work (F-G, 15 days) and Electrical Work (N, 6 days). Third, Concrete Work (D), with the longest individual duration of 17 days, serves as the primary bottleneck that governs the earliest possible start time for all subsequent activities. Idris & Islami (2025) emphasize that any delay in the execution of activities along this *critical path* will directly extend the total overall project duration without any slack time. Therefore, time control recommendations must be strictly prioritized on this route, especially on synchronizing the sequence of Roofing Work (H) and Ceiling Work (I), which requires precise labor transition so as not to create a *bottleneck* in the field.

The six activities identified as *non-critical* provide varying scheduling flexibility. Earthwork (B) with a TF value of 3 days is the most sensitive *near-critical* activity because it is prone to turn into a critical activity if it experiences even the slightest disruption in the field. Saputra et al. (2024) remind that activities with such minimal slack time require intensive and continuous monitoring by the project manager to avoid a domino effect of delays. On the other hand, the large float value in the remaining *non-critical* activities provides very high scheduling flexibility for the allocation of labor and materials, so potential resources can be diverted to support the acceleration of activities on the *critical path* if necessary (Mufahri & Oetomo, 2023). The large Total Float values of Sanitation Work (M, TF = 52 days) and Electrical Work (N, TF = 42 days) provide three significant benefits for project resource management. First, the workforce assigned to these activities can be scheduled flexibly without risk of delaying the overall project, as Sanitation Work can be deferred by up to 52

days without any impact on the project completion date. Second, during periods of schedule pressure on the critical path, labor from these two activities can be temporarily reallocated to accelerate critical activities such as Ceiling Work (I) or Painting Work (L). Third, materials and equipment for these activities do not need to be procured at the project outset, thereby reducing early-stage working capital requirements and providing greater cash flow flexibility for the developer. Overall, the CPM analysis resulted in an optimal project completion duration of 87 working days. This result shows a consistent logical correlation in project time management, where the figure of 124 days is the total linear accumulation if the work is forced to run sequentially, the figure of 120 calendar days is the target limit from the developer, while the figure of 87 working days is the estimated project duration obtained through CPM-based parallel scheduling. This finding is consistent with the results of research on local housing scheduling in Samarinda by Surahman, Saputri, et al. (2024) and Surahman, Kusumah, et al. (2024), which proved that a network-based quantitative approach is able to significantly reduce project duration through logical relationship optimization.

The CPM analysis not only identifies the *critical path* and project duration, but also provides a basis for formulating practical scheduling recommendations. Activities with a total float of zero are critical and require strict time control, as any delay will directly extend the overall project duration. Earthwork (B), although non-critical, carries only 3 days of float and is therefore classified as near-critical, demanding monitoring intensity comparable to that of critical activities. Table 3 presents the risk factors and recommended control actions for each of these priority activities.

Table 3. Practical Scheduling Recommendations for Critical and Near-Critical Activities

Activity	TF (days)	Status	Risk Factor	Recommendation
B – Earthwork	3	Near-Critical	Rain, unstable soil condition, labor delay	Monitor daily progress and prepare equipment/materials early
H – Roofing Work	0	Critical	Material delivery delay, weather disruption	Ensure roofing material before E finishes
I – Ceiling Work	0	Critical	Entirely dependent on Roofing Work completion	Prepare workers and materials before H ends
L – Painting Work	0	Critical	Surface readiness and paint drying time	Check wall moisture before starting and ensure adequate drying time between coats

Source: Data processed by authors, 2026

CONCLUSION

This study applied the Critical Path Method to the Type 36 residential construction project at Grand Permata Hijau Housing, Samarinda. The analysis identified the *critical path* as **A → C → D → E → H → I → J → L → O**, with an estimated project duration of 87 working days. Compared with the initial 120-calendar-day target, the result indicates potential schedule efficiency, although the comparison should consider the difference between working days and calendar days. The findings show that time control should prioritize critical activities, especially roofing, ceiling, wood and frame work, and painting. Earthwork also requires close monitoring because it has only three days of float; being a near-critical activity, any delay caused by rain, unfavorable soil conditions, or labor disruptions could readily exhaust its remaining slack and convert it into a critical activity, extending the overall project duration. In addition, the analysis identified six non-critical activities with varying degrees of scheduling flexibility, where Electrical Work (TF = 42 days) and Sanitation Work (TF = 52 days) offer the greatest opportunities for labor and resource optimization. Future studies should integrate CPM with cost analysis, resource allocation, or Critical Chain Project Management to produce more comprehensive project control recommendations. The integration of

CPM with cost analysis would enable project managers to optimize not only time but also expenditure, by identifying activities where schedule acceleration can be achieved at the lowest marginal cost through time-cost trade-off analysis. Integration with resource allocation would allow systematic redistribution of labor and equipment from high-float activities such as Sanitation Work (TF = 52 days) and Electrical Work (TF = 42 days) to critical path activities requiring acceleration. These integrations would address time, cost, and resource dimensions simultaneously, improving construction project performance beyond what scheduling alone can achieve. The findings also carry practical implications for subsidized housing projects in other regions, as the CPM approach applied here is directly replicable with activity durations and predecessor relationships adjusted to reflect local conditions, positioning CPM as an accessible, low-cost project management tool suited to the operational realities of subsidized housing developers across Indonesia.

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