Time and Cost Optimization of the Coordinating Ministry 4 Office Building Construction in Nusantara Using the Time-Cost Trade-Off Method

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ABSTRACT

This research aims to analyze the acceleration of the construction project for the Coordinating Ministry 4 office building in the Nusantara capital city in terms of cost and time. Additionally, it examines the optimization of the final total cost and project completion time after acceleration. The Time Cost Trade Off (TCTO) method is used to evaluate an acceleration alternative that replaces the construction method with a more effective one. Specifically, the work method for the floor slab structural element is changed from conventional concrete to precast concrete (half-slab). The half-slab method is a type of precast concrete construction for floor slab structural elements. The analysis shows that using the half-slab method as an acceleration alternative was effective for constructing the office building of the Coordinating Ministry 4 in the Nusantara Capital City project, reducing the total work time from 392 days or 56 weeks to 363 days or 52 weeks. The cost also changed, with the normal cost increasing from Rp 29,874,122,004.42 to Rp 29,901,677,798.806, achieving an optimization value of Rp 29,718,483,194.103 and a total time acceleration of 29 days or 4 weeks. These results provide an important overview of the work optimization for improving the future construction management and can serve as a cost-efficiency and time management reference.

Keywords-Time Cost Trade Off (TCTO) method; half-slab; optimization; time; cost

I. INTRODUCTION

In the construction industry, delays can lead to significant financial losses, so it is important to complete projects on time for successful management. As projects become more complex and clients expect faster delivery, reducing the project duration without compromising the quality has become important. Project time compression [1-3] can be achieved through schedule optimization, increased resource allocation, activity overlap (fast-tracking), and the selection of more efficient construction methods. The TCTO method, one of the most widely applied methods for schedule acceleration [4], helps project managers identify the most cost-effective way to shorten a project's duration by evaluating the trade-offs between time and cost. It involves adjusting activity durations through additional resources or alternative methods while assessing the resulting cost implications. While time compression can lead to earlier project completion, it also introduces risks, including increased costs, potential resource overloading, and reduced quality [5-7]. Therefore, it is essential to carefully analyze the effects of schedule acceleration strategies to ensure compliance with the project goals. This research uses the TCTO method on a construction project as a case study to determine the optimal schedule that meets the project's deadline with the least possible cost increase. The goal is to promote more informed decision-making in project planning by showing how TCTO can balance time, cost, and quality. The TCTO method analyzes the connection between project duration and associated costs using techniques, such as crashing (accelerating specific activities by adding more resources), fast-tracking (overlapping sequential tasks), and resource leveling (solving resource problems without changing the goals of the project) [8-12]. To improve the construction efficiency, precast elements can be used (half-slab system), that are half the height of a standard floor slab. The components are produced outside of the construction site and assembled on-site, reducing the construction time, labor demands, and potential delays. Despite these advantages, integrating such methods into a cost-time optimization framework, like TCTO, is not always easy [13]. This study evaluates the impact of the half-slab system on the project duration and cost under various schedule compression strategies, by providing practical information on how combining innovative building methods with optimization tools can improve the project delivery outcomes. Ultimately, the findings offer project managers guidance on delivering projects efficiently without compromising the quality or exceeding the budget constraints.

II. RESEARCH METHODOLOGY

Management is essential for ensuring the efficient and effective functioning of an organization. The primary challenge project managers confront is the effective usage of project resources and goals, particularly in regard to time, cost, and personnel. The integration of project management principles results in significant advantages, including time and cost savings. The research is conducted as part of the Field Work Practice (PKL) program, which is an academic initiative that enables students to acquire practical experience in real-world projects related to their field of study. The present PKL was carried out over a period of approximately four months, from August 4, 2023, to December 10, 2023. During this period, the research concentrated on the construction project of the office building of the Coordinating Ministry 4 for the Nusantara Capital City—Indonesia's future capital. The project site is situated in North Penajam Paser Regency, East Kalimantan province, as shown in Figure 1, which is one of the primary regions assigned for national government infrastructure development. The primary objective of the current research is to analyze and evaluate the factors contributing to the delays in the construction process of this government building. This includes a review of various aspects, such as planning, scheduling, resource management, contractor performance, weather conditions, and supply chain issues. The objective of this evaluation is twofold: first, to identify the causes of the delays, and second, to propose strategies to improve the efficiency and prevent similar setbacks in future phases of the Nusantara development. The study combines field observations, interviews with project stakeholders, and analysis of the project documentation, including progress reports and construction schedules. The research method, is the TCTO approach and the application of half-slab (precast concrete) construction to achieve project acceleration by using Microsoft Project software, as presented in the flowchart in Figure 2. The required data are obtained from related agencies, such as contractors and supervising consultants. The data necessary for the time component is: time schedule (S curve), recapitulation of project cost calculations, milestone recap, weekly progress report, and a list of the cost components. The following data are required for the cost components: list of Budget Plan (RAB), list of material prices and wages, the direct and indirect cost, and the unit price analysis.

(a)

(b)

Fig. 1. Location of the Kemenko 4 IKN office building construction project: (a) 4/8/2023, (b) 10/9/2023, as seen by drone.

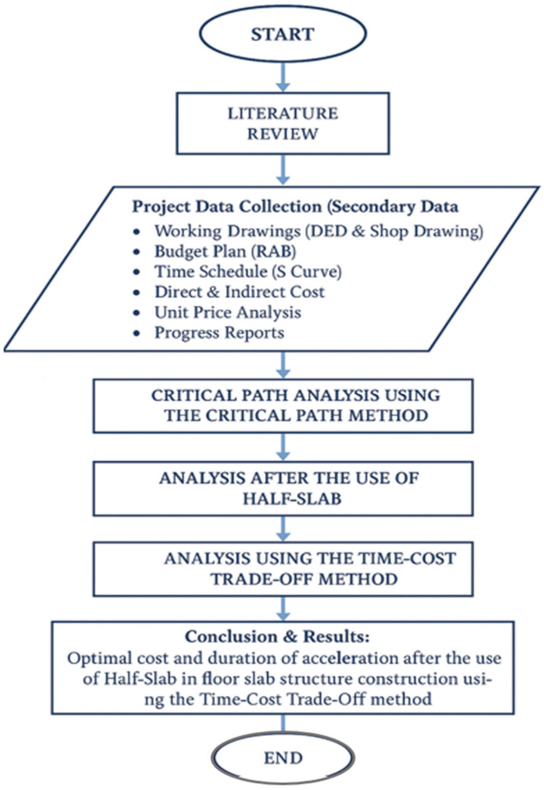

Fig. 2. Flowchart.

III. RESULTS AND DISCUSSION

A. Critical Path Method Analysis

1) Rescheduling

In this project, a rescheduling is needed due to the delays that occurred in the 7th week. It is necessary to determine how much time is required to complete the project, as well as to know the schedule of each work activity being carried out in the field. In this study, the project rescheduling will only review the upper structure work, specifically on the tower 4 structure, as displayed in Table I.

TABLE I. THE ACTIVITIES AND TIME REQUIRED

Activity	Time (weeks)
Structural Work on Tower 4	
Tower 4 Floor 1	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	3
Tower 4 Floor 2	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Floor 3	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Floor 4	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Floor 5	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Floor 6	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Roof Floor	
Column Work	3
Tie Beam/Beam Work	3
Floor Slab Work	4
Tower 4 Roof Top	
Tie Beam/Beam Work	3
Floor Slab Work	4

2) Preparation of the Work Network

In order to determine the schedule and the durations of activities, a time schedule can be created, by using the Critical Path Method (CPM). This method has the ability to assist in the process of creating a work network, which can then be used to calculate the time for each activity, including the earliest and latest completion times, the earliest and latest start times for an activity, etc. The application of the CPM has enabled the identification of lists of critical activities. The critical path must be determined by first identifying the existing work network depicted in Table II. This will then be converted into a work network diagram, consisting of the following: an arrow is used to represent the ongoing activity, with the direction of the arrow indicating the direction of the activity; a circle (node) is used to represent an event; and a dashed arrow (dummy) is used to indicate a hypothetical activity, demonstrating a relationship between two activities, as portrayed in Figure 3.

TABLE II. WORK NETWORK ARRANGEMENT

Activity	Code	Predecessor	Successor	Duration (weeks)
Tower 4 Floor 1				
Column Work	B	-	C,D	3
Tie Beam/Beam Work	C	B	E	3
Floor Slab Work	D	B	E	3
Tower 4 Floor 2				
Column Work	E	C,D	F,G	3
Tie Beam/Beam Work	F	E	H	3
Floor Slab Work	G	E	H	4
Tower 4 Floor 3				
Column Work	H	F,G	I,J	3
Tie Beam/Beam Work	I	H	K	3
Floor Slab Work	J	H	K	4
Tower 4 Floor 4				
Column Work	K	I,J	L,M	3
Tie Beam/Beam Work	L	K	N	3
Floor Slab Work	M	K	N	4
Tower 4 Floor 5				
Column Work	N	L,M	O,P	3
Tie Beam/Beam Work	O	N	Q	3
Floor Slab Work	P	N	Q	4
Tower 4 Floor 6				
Column Work	Q	O,P	R,S	3
Tie Beam/Beam Work	R	Q	T	3
Floor Slab Work	S	Q	T	4
Tower 4 Roof Floor				
Column Work	T	R,S	V	3
Tie Beam/Beam Work	U	T	V	3
Floor Slab Work	V	T	V	4
Tower 4 Roof Top				
Tie Beam/Beam Work	W	V	-	3
Floor Slab Work	X	V	-	4

Source: personal data processing, 2024

The development of a project scheduling diagram (e.g., a network diagram) requires the following:

- A unique activity code or identifier is important for each work item, as it facilitates the clear reference and organization of tasks.
- The establishment of logical relationships between activities (e.g., finish-to-start, start-to-start) is necessary for the development of effective task sequencing.
- The estimated duration of each activity is typically expressed in working days or hours.
- The calculation of the scheduling parameters, including Early Start (ES) and Late Finish (LF), along with other critical path data derived through schedule analysis, is essential for effective project management.

The construction of Tower 4 in the Coordinating Ministry office building at Nusantara Capital follows a repetitive structure across its floors, each comprising three sequential activities: column work, tie beam/beam work, and floor slab work. The tasks are logically arranged with clear dependencies, making the project suitable for CPM and TCTO analysis. It is noteworthy that while the majority of activities have a fixed duration of three weeks, the floor slab work requires a duration of four weeks from the second floor onward.

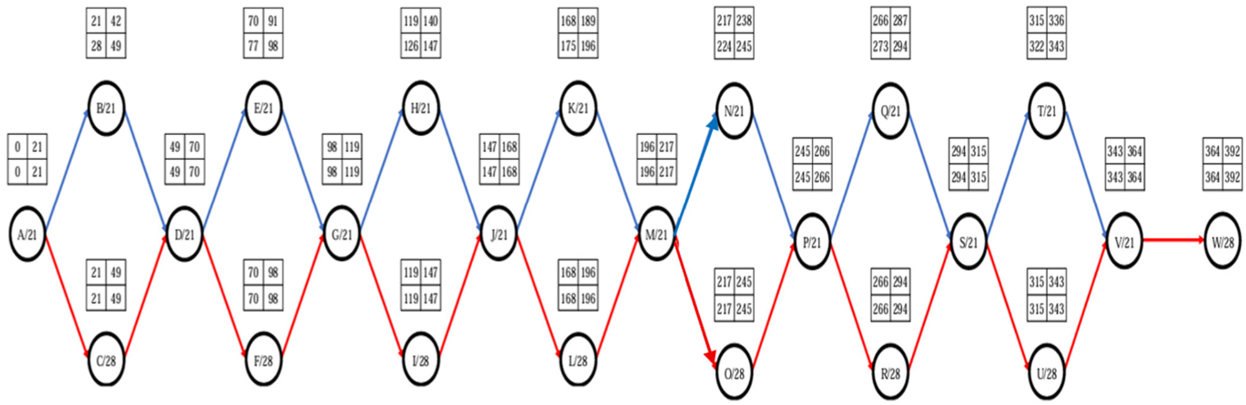

Fig. 3. The CPM diagram.

This observation suggests that the floor slab work may involve a higher degree of complexity or extended curing times at elevated levels. A critical path analysis reveals that the floor slab activities, especially those occurring from the second floor to the rooftop, consistently lie on the longest path and significantly influence the total project duration. The TCTO method provides the greatest potential for schedule reduction by crashing these slab activities. The project team can assess the cost-effectiveness of accelerating each task using cost slope analysis. For instance, a reduction in the duration of each 4-week slab task by 1 week could result in a cumulative reduction of 6–8 weeks in the project's duration, contingent upon the availability of resources, effective logistics, and seamless coordination to facilitate parallel task execution. In order to support this strategy, it is important to use precast half-slab systems, adjust the labor shifts, and manage the formwork efficiently. Furthermore, the adoption of Building Information Modeling (BIM) can enhance the schedule visualization and coordination. Additionally, alternative slab systems and a robust risk mitigation framework are proposed to ensure quality and sustainability under accelerated timelines. The findings of this study indicate that the slab work is the primary factor contributing to the project's delay. The adoption of the TCTO method results in quantifiable enhancements in terms of time and cost efficiency. This approach functions as a scalable model for the management of analogous high-rise government projects, particularly within Indonesia's evolving capital region. Following this time-cost strategy improves the schedule performance and aligns with broader construction management goals, such as reducing the overheads, minimizing disruption, and ensuring a better cash flow across project phases. Furthermore, the practice of deliberate over-consumption, or selective crashing, helps to prevent the unnecessary expenditures on non-critical activities. This, in turn, enables a more effective allocation of resources, which are used in activities that yield the greatest return. The results of this study offer practical insights for the management of high-rise government infrastructure projects under tight timelines. By prioritizing data-driven methodologies, such as TCTO, and incorporating digital tools, like BIM, the project teams are able to make informed, strategic decisions that enhance the efficiency. According to the analysis, the following step is to identify the work items that lie on the critical path. The latter is defined as a sequence of activities where the EF and LS values are equal, resulting in zero total float, as shown in Table III.

TABLE III. WORK ON THE CRITICAL PATH

No	Activity	Duration (weeks)
1	Floor Slab	4
2	Floor Slab 1	4
3	Floor Slab 2	4
4	Floor Slab 3	4
5	Floor Slab 4	4
6	Floor Slab 5	4
7	Floor Slab 6	4
8	Roof Floor	4

Source: personal data processing, 2024

B. Application of the Time Cost Trade Off Method

In order to develop an efficient construction approach, this study employs the half-slab method to increase the speed of the floor slab construction. Before estimating the potential time reduction, it is essential to calculate and compare the volume of concrete required for the conventional slab system and the half-slab system. This comparison is a fundamental step in determining not only the efficiency in terms of the construction time, but also the impact on the material usage, cost implications, and overall structural performance. The analysis of these parameters is essential for the study to provide a more comprehensive evaluation of whether the half-slab method offers significant advantages over the conventional system in practical applications, as presented in Table IV.

TABLE IV. RECAPITULATION OF FLOOR SLAB CONCRETE VOLUME

	Vol. Pelat Beton	Vol. Half-Slab	Vol. Konvensional
Floor 1	260.765	-	-
Floor 2	229.626	56.02	173.606
Floor 3	211.831	47.49	164.341
Floor 4	182.24	35.48	146.76
Floor 5	192.562	46.43	146.132
Floor 6	172.145	36.83	135.315
Roof Floor	178.563	-	-
Roof Top	111.337	-	-

1) *Crash Duration*

The calculation of the crash duration is used to ascertain the maximum permissible limit for an activity to be capable of being crashed. Table V illustrates the calculations regarding the crash duration for each task on the critical path, with the acceleration calculation strictly considering the critical path within the floor slab structure.

TABLE V. COMPARISON OF NORMAL DURATION WITH ACCELERATED DURATION

No	Activity	Code	Normal Duration	Acceleration Duration
1	Floor Slab 2	F	28	22
2	Floor Slab 3	I	28	22
3	Floor Slab 4	L	28	23
4	Floor Slab 5	O	28	22
5	Floor Slab 6	R	28	22
Total Duration of Work			Total Work Time	Total Work Time

2) *Calculation of Cost Slope*

Cost slope is the increase in cost due to additional work to accelerate an activity per unit of time. Table VI portrays the cost slope calculations for each task that has undergone acceleration, while Table VII shows a comparison of the total cost calculation.

TABLE VI. CALCULATION OF ADDITIONAL WORK (WIRE MESH M8-150)

Wire mesh Work	Unit	Volume	Unit Price	Total Price
Floor 2	Kg	5,161.65	17,615.00	90,922,527.03
Floor 3	Kg	4,761.65	17,615.00	83,876,477.94
Floor 4	Kg	4,096.49	17,615.00	72,159,748.82
Floor 5	Kg	4,328.51	17,615.00	76,246,664.63
Floor 6	Kg	3,869.57	17,615.00	68,162,446.51

TABLE VII. COMPARISON OF TOTAL COST CALCULATION

No	WOEK	Vol (M3)	Normal Cost (IDR)	Acceleration Cost (IDR)	Cost Slope (IDR)
1	Floor Slab 2	229.626	539,612,858.11	672,244,746	22,105,314.7
2	Floor Slab 3	211.831	497,795,513.01	610,231,935	18,739,403.7
3	Floor Slab 4	182.24	428,258,315.85	512,260,089	16,800,354.8
4	Floor Slab 5	192.562	452,513,606.51	562,440,392	18,321,131.0
5	Floor Slab 6	172.145	404,534,869.13	491,732,877	14,533,001.4

Once the cost slope value for each activity is obtained, the next step involves the time compression process for the activities that are on the critical path according to the standard network planning conditions. The compression process commences with the critical activities that exhibit the lowest cost slope value. The objective of this approach is to minimize the increase in direct costs resulting from the compression. The reduction in project duration due to compression generally results in a decrease in the indirect costs. In order to ascertain the amount of indirect costs that can be conserved, it is important to compress them. Figure 4 presents the project scheduling network for Project F, highlighting the critical path and the durations associated with each task. Each node in the network corresponds to a particular activity, specified using a combination of letters and numbers. The connections between these nodes represent the dependencies between the activities. By accelerating specific tasks, marked in green, the project's duration can be reduced to 363 days. The pathways presented in blue and red are indicative of disparate scheduling options, with the red pathways denoting accelerated tasks to optimize the temporal efficiency.

3) *Final Calculation of Total Cost*

Based on the Regulation of the Government Goods and Services Procurement Policy Agency Number 12 of 2021 and Presidential Regulation Number 70 of 2012 Article 66 Paragraph 8 concerning Goods and Services Procurement, indirect costs are calculated at 15% of the total project cost. Table VIII presents the results of the cost and time optimization calculations for various activities, comparing a normal duration with several accelerated options. The normal activity requires 392 h and incurs a total cost of IDR 29,874,122,004.42, making it the most expensive option. In contrast, the accelerated activities vary in both the duration and cost. For instance, the R accelerated activity lasts 386 h with a total cost of IDR 29,901,677,798.806, while the O accelerated option takes 375 h and costs IDR 29,789,137,506.175. The L accelerated activity has a similar direct cost but slightly higher total costs at IDR 29,861,764,363.02 for 380 h. The I accelerated activity requires the least time at 369 h and costs IDR 29,757,929,941.509, while the F accelerated option is the most cost-effective with a duration of 363 h at IDR 29,718,483,194.103.

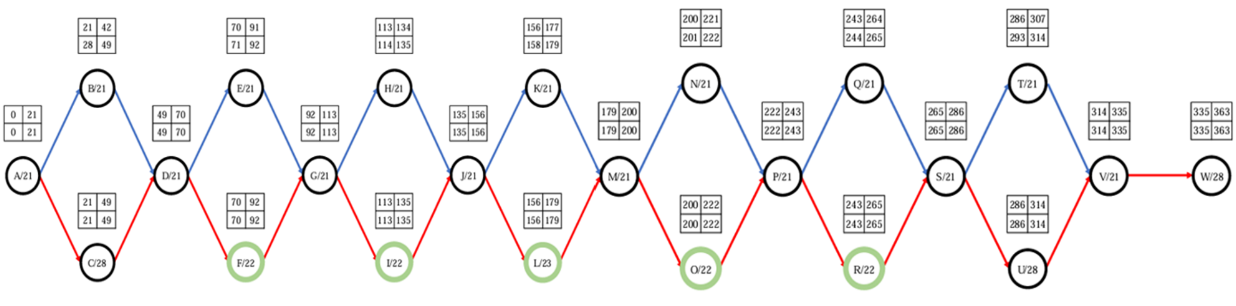

Fig. 4. The acceleration of F-L-I-O-R.

Figure 5 presents the relationship between the time and cost for the project, showing how the total cost fluctuates as the duration is reduced. The horizontal axis denotes the duration in days, ranging from 386 to 363 days, while the vertical axis indicates the total cost in IDR. As the duration of the project decreases, the cost initially shows a downward trend, with a notable drop as the project is accelerated. The lowest point on the graph corresponds to the shortest duration of 363 days, reflecting the most cost-effective option.

TABLE VIII. RESULTS OF COST AND TIME OPTIMIZATION CALCULATIONS

Activity	Duration (days)	Direct Cost (IDR)	Indirect Cost (IDR)	Total Cost (IDR)
Normal	392	25,977,497,395.15	3,896,624,609.27	29,874,122,004.42
R accel.	386	26,064,695,403.02	3,836,982,395.786	29,901,677,798.806
O accel.	375	26,084,424,180.64	3,727,638,337.875	29,789,137,506.175
L accel.	380	26,084,424,180.64	3,777,340,182.38	29,861,764,363.02
I accel.	369	26,089,933,817.14	3,667,996,124.369	29,757,929,941.509
F accel.	363	26,110,129,283.04	3,608,353,911.063	29,718,483,194.103

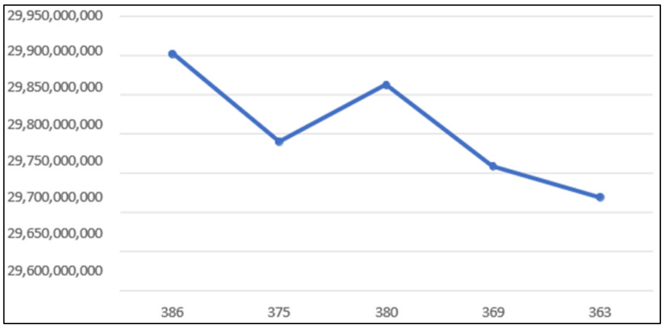

Fig. 5. Time and cost graph.

The accelerated construction of the Coordinating Ministry 4 office building project at the Nusantara Capital City, using TCTO method in combination with the half-slab precast system, underscores the effectiveness of innovative construction technologies in achieving project optimization in terms of schedule and cost. The findings of this study indicate a schedule reduction of 29 days, resulting in a revised project duration of 363 days, accompanied by significant cost optimization. The application of the half-slab construction technique played a crucial role in the project's critical path activities, leading to a substantial reduction in the overall schedule. The off-site fabrication of structural elements has been shown to reduce the on-site labor requirements and accelerate the installation processes, thereby reducing the delays often associated with conventional in-situ concrete methods [14]. This outcome reflects the current trends in the construction industry that prioritize the usage of prefabricated components to optimize the efficiency and productivity. Despite an increase in direct costs attributed to additional requirements, such as wire mesh reinforcement and specialized logistics for precast component handling, the overall project cost exhibited optimization when indirect costs were accounted for [15]. The reduction in the project duration resulted in decreased overhead and general project administration expenses, thus offsetting the increase in the direct construction costs. Consequently, the strategic combination of the TCTO method with modern construction technologies, such as half-slab, was found to be a viable approach for project acceleration without significantly compromising the budgetary constraints [16-18]. Authors in [19] described that the damage to structural materials during storage, lack of designated storage space for materials, design inconsistencies with on-site work, and changes in material orders are factors that affect the project financing. An analysis of the project's critical path reveals that the floor slab construction is a significant factor affecting the project schedule.

IV. CONCLUSIONS

The results of the project acceleration calculation, using the Time Cost Trade Off (TCTO) method on each task within the critical path, particularly the floor slab structure work with the addition of half-slab usage as a more effective construction method, indicate that the normal work time is 392 days and after the acceleration calculation, it is obtained as 363 days. The cost calculation, which was performed using the TCTO method, revealed that the total cost prior to the acceleration calculation was Rp. 29,874,122,004.42, and after the acceleration calculation, the total cost increased to Rp. 29,901,677,798.806. The discrepancy between the standard duration and the optimal duration is 29 working days, while the disparity between the standard cost and the optimal cost is Rp. The total amount of the settlement was $155,638,810.317. The results of the optimal time and cost calculations obtained from the TCTO method should be considered, because the optimization of the time-cost results can shorten the completion duration and reduce the implementation costs compared to normal duration conditions. Further development of the research on project time and cost optimization using the TCTO method can be achieved by exploring additional acceleration alternatives.

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