P-ISSN 1858-2192 | E-ISSN 2686-5467
BALANCE JURNAL EKONOMI
PENERBIT: PROGRAM STUDI ILMU EKONOMI DAN STUDI PEMBANGUNAN FAKULTAS EKONOMI DAN BISNIS UNIVERSITAS MUHAMMADIYAH MAKASSAR

Implementation of Time Management Using the Critical Path Method (CPM) in the Construction of School Buildings

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Keywords:

Project Management, School Building Construction Project, CPM.

Abstract

School building construction projects often face challenges, especially delays in project completion. These delays often cause projects to exceed the schedule set in the contract. This study aims to identify the main factors contributing to project failure by analyzing the project schedule using the Critical Path Method (CPM). By identifying activities on the critical path, this study highlights which tasks have the highest potential to cause delays if not managed properly. This research method uses a quantitative descriptive approach with primary data collected through interviews with construction companies. The CPM analysis of the project schedule reveals a network diagram detailing a series of activities, with nine activities identified on the critical path. These activities have the longest duration and directly affect the overall project completion time. The results of the study show that from the application of the critical path method (CPM) analyzed by the author on the school building construction project, it can be concluded that there are several jobs that pass the critical path. The time needed to carry out the construction of the school building was accelerated to 30 with a cost of Rp. 216,497,434.

1. Introduction

The construction of school buildings is a series of planned and time-limited activities to build or renovate buildings used as educational facilities that are more suitable, safe, and comfortable for students and educators (Rini 2021). This is because education is one aspect of development that is simultaneously the main requirement for realizing national development. This is in line with Law No. 20 of 2003 concerning the national education system which states that the purpose of education is to develop abilities and also improve the quality and dignity of the Indonesian people in an effort to achieve national ideals. National development is also mentioned in the 2005-2009 Ministry of Education and Culture's strategic plan (Renstra), which states that one of the purposes of national education development is to equalize learning opportunities in all paths and levels of education.

One important part of educational facilities and infrastructure is the building and classroom buildings, with comfortable and conducive school buildings greatly influencing the smooth running of the education process (Rani 2016) According to the Decree of the Minister of Public Works and Public Housing Number 332/KPTS/M2002 concerning the technical guidelines for the Construction of State Buildings, a building is a building that functions as a place for teaching and learning activities. School building construction projects often face various challenges, one of which is the delay in completion (Suwito 2021).

The main problem experienced is the high delay in the project completion schedule, therefore the work cannot be completed according to the stated work contract (Rosyada, n.d.). The success or delay in completing a project depends on the preparation of plans, schedules and control, the longer the project takes to complete, the greater the costs and time spent (Rizal, Fay, and Krisnayanti 2024). As stated by Aulady and Orleans (2016), one of the main problems in the project is suboptimal activity scheduling.

CV Prima Karya is a company engaged in the construction sector and plays a role in various infrastructure projects. As a player in the construction sector, CV Prima Karya focuses on several developments including public facilities such as the construction of school buildings, with the aim of producing quality buildings and completing them on schedule. CV

Prima Karya has been using inappropriate methods in completing its projects so far, so there are still delays in completion. The following are the targets and realizations of projects that CV Prima Karya has worked on for the past 1 year.

Table. 1 Target and Realization of CV Prima Karya projects

Project Name	Target Completion	Realization of Completion	Delay
Construction of secondary water channel dam	2 Month	2 Month	-
Construction of embankment pondang embankment	1 Month	1 bulan	-
Construction of school building	1 Month	1 Month 3 Days	3 Days

Source : CV Prima Karya

In this regard, the critical path method (CPM) is one of the appropriate methods to help solve problems in the school building construction project faced by CV Prima Karya, as stated by Alan Muin (2022) CPM is an important tool to help overcome problems, with CPM, each activity in the project is identified and also systematically sorted according to the critical path, namely activities that determine the total duration of the project. The CPM method (critical path method) can be used to identify a project activity involvement between activities. Activities, namely, work that produces work whose processing time is measured (Rosanty et al 2016). One of the advantages of the word CPM (critical path method) is that it is suitable for formulating, scheduling, and managing various activities in all construction work, because it provides a schedule that is built in real terms (Adedji and Bello 2014).

The application of CPM has been widely carried out by previous researchers. This shows the importance of controlling and organizing time in a project. One of the relevant researchers was carried out by Muhassanah and Khozinati (2021) with research content discussing the application of CPM to the Kedungrandu Regency housing project. The results of this study stated that using CPM was able to determine the critical path, and using CPM was very effective in helping to make planning and control project time. Another study was also conducted by Husna et al (2022) this study applied the CPM (critical path method) and PERT methods to the Al-Ikhlas prayer room construction project in Central Kalimantan.

This study stated that CPM is effective in optimizing project duration by ensuring that critical activities are detected and managed properly. Although the CPM method has been widely applied, the dominant research focuses on projects with large scale projects such as building and road construction. Although the Critical Path Method (CPM) has been widely used in construction projects in general, most studies are still focused on large-scale projects such as the construction of road infrastructure, bridges, or commercial buildings. Research that specifically examines the effectiveness of CPM on school building construction projects is still limited, especially in the context of educational environments that have unique characteristics, such as budget constraints, tight deadlines based on the academic calendar, and complex stakeholder involvement (government, schools, communities).

In addition, some existing studies have not explicitly compared time planning using CPM with conventional approaches in school projects, so the effectiveness of this method in the educational context has not been fully described. Therefore, this study is important to fill this gap by presenting the practical application of CPM in school building construction, while evaluating the potential for time efficiency and project control produced. This study specifically explores the application of CPM for small-scale projects or projects with limited resources that are still rarely found. This study analyzes how the application of the

critical path method to school building construction, where the path with the longest total duration of work is the critical path. The analysis applied in this study is network planning which is applied to analyze the critical path and analyze the comparison of costs and time due to acceleration. This study was conducted to avoid delays in project completion in the future and to determine the number of paths formed in the network and to determine the activities included in the critical path to determine the duration of the implementation time and costs incurred on work that crosses the critical path.

Delays in project completion will cause contractors to experience losses in costs and time, because the contractor's expected profits can be reduced or even no profit at all (Casa et al. 2020) . Thus, the purpose of this study is to help determine the main factors that can cause project failure by analyzing the critical path method and identifying work activities included in the critical path so that it can be known which activities have the potential to cause project delays if no special attention is paid.

2. Literature Review

2.1 Project Management

Project management is a practice that aims to plan, organize and control resources, time and costs so that projects can be completed according to time and on target (Management 2024). According to Donato, (2023) project management is the process of project planning, organizing, and managing resources to achieve project goals within a certain period of time. While in practice, project management strives to be able to complete projects efficiently to minimize costs and achieve goals related to customer needs (Al-Hajj, A., & Zrauning 2018). Rani (2016) project management is the process of planning projects, organizing projects, leading, and controlling company resources to achieve predetermined short-term goals. From the several definitions above, it can be concluded that project management is the process of planning, organizing and resources to achieve project goals within a certain time while minimizing costs. Some methods in project management are PERT Charts, Gantt Charts, CPM, Event Chain Diagrams and others.

2.2 Critical Path Method (CPM)

Critical Path Method (CPM) or the critical path method is a path that has a sequence or parts of activities with the longest total time and shows the fastest project completion period (Berman 2021). The CPM method was first used and developed in England in the mid-50s in a power plant project. Critical Path Method (CPM) is a project management technique used to plan and schedule activities in a project (M. Elfan Kaukab, Yusqi 2019). Wicaksono and Setiawan (2023) said that the critical path method is a project activity model that is described in the form of a network. As in the study conducted (Azmi et al. 2022). on the planning of the construction of basic education facilities. This study was conducted at an elementary madrasah (MI), focusing on the management of school construction project time. The results of the study showed that the CPM method was very helpful in identifying the critical path of all construction activities, making it easier to map activities that should not be delayed.

The activities described are used as points on the network and events that indicate the beginning or end of the activity as lines between points (Lingkarlsm 2019). Critical Path Method (CPM) is a method in project management that is used to help identify the path of activities that most determine project completion or is commonly called the critical path (LinovHR 2023). As stated by (Asana 2024), CPM aims to map an activity in a project and identify activities that have an impact on the duration of the project. The following are the steps in making CPM

a. Create and compile a list of jobs
   The first step in implementing the critical path method (CPM) is to compile and create a list of work activities that will be included in the CPM by determining the identification such as codes for each job
b. Calculate the duration of the job

After compiling a list of work activities, the next step is to calculate the duration (time) that will be needed to complete each job individually.

c. Determine the relationship between jobs
At this stage, it is necessary to determine the relationship between work activities, each activity is analyzed to find out which ones will precede (predecessor), and which activities will follow (successor). This relationship is the basis for compiling a work network.

d. Describe the work network
The identified jobs are then reconnected in the form of a work network by listing the work codes and durations that are interrelated and the relationship between activities to provide a visualization of the flow of interrelated work.

e. Identify critical paths / trajectories
After the work network (Network), the next step is to analyze the critical paths or trajectories in the work network. The critical path is a series of jobs that determine the total duration of the project. Activities on this critical path require special attention because any delay will impact the entire project schedule.

f. Compiling a CPM table
In accordance with the results of the critical path identification analysis, the next step is to compile it in the form of a CPM table. This table includes a summary of activities, durations, relationships between jobs, and critical paths that help in decision making and controlling the project schedule.

3. Research Methods

In this study, the method applied is the descriptive quantitative method. Descriptive quantitative is a method that helps describe/show existing data that will be re-arranged to be explained and re-analyzed 5 (Aziza 2023). The data collection technique used in this study was primary data by conducting interviews with the CV Prima Karya Company and secondary data in the form of project planning time/time schedule from CV Prima Karya. The data taken in this study were in the form of numbers with the aim of determining the efficiency of project opportunities that could be completed according to the target using the critical path method (CPM) to determine several jobs that could be passed through the critical path and processed using POM QM software for windows. The location of this research is on Jln. Kusuma Bangsa Gg. Beringin III Lamongan

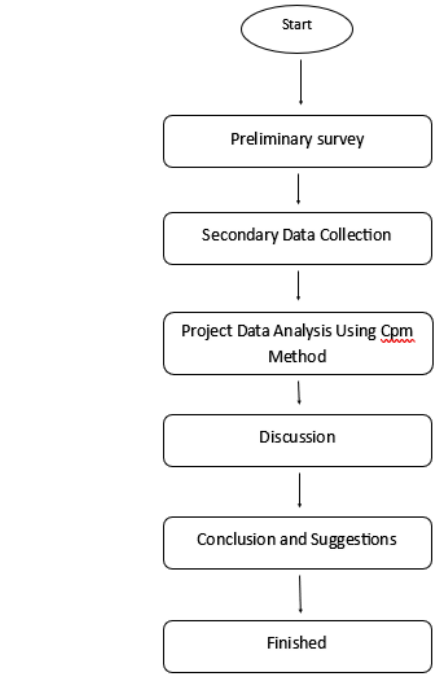


Figure 1. Research Flowchart

4. Results and Discussion

4.1 Job Description

In the school building construction project, there are several work items that cover the initial preparation stage until the work is finished. The following is a description of the work in the school building construction project.

Table 2. Job Description, code and duration

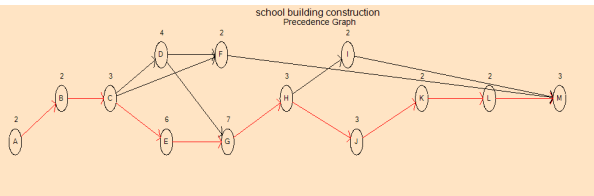
No	Work Item	Code	Duration
1	Preparation work	A	2 Days
2	Earthwork and demolition	B	2 Days
3	Foundation work	C	3 Days
4	Wall work	D	4 Days
5	Concrete work	E	6 Days
6	Plastering work	F	2 Days
7	Iron work	G	7 Days
8	Roof covering work	H	3 Days
9	Ceiling work	I	2 Days
10	Aluminum work	J	3 Days
11	Wood work	K	2 Days
12	Key and glass work	L	2 Days
13	Electrical work	M	3 Days

Source : Processed Data (2024)

4.2 Critical path method (CPM)

1. Collecting data on project activities and time
   Collecting data on activities and project work time during the normal time of school building construction can be seen in table 2.
5. Building relationships between activities
   This data is about the relationship between project activities and other project activities that are arranged based on the previous work that needs to be completed first before the next activity begins. Details of the predecessor activities can be seen in table 2.
2. Building a network diagram
   Based on the relationship between activities and estimated time (estimate age), thus, a network diagram can be compiled that describes the sequence of activities in the school building construction project as follows.

Figure 2. Network Diagram From POM QM for Windows



Source: Processed Data (2024)

4.3 Calculating SPA, SPL, and time limits for each activity

The next step in the school building construction project is to calculate SPA (Start Point Analysis), SPL (Slack Point analysis), and time limits for each activity in the project. The goal is to identify critical activities in the network diagram that has been created using POM QW for Windows software. The following is the calculation of SPA, SPL, and time lag data for each activity in table 3.

Table 3. Result of SPA, SPL, and Time Lag Calculation Activity Code SPA, SPL,Time Lag (Slack)

Kode kegiatan	SPA	SPL	Tenggang Waktu (Slack)
A	0	0	0
B	2	2	0
C	4	4	0
D	0	9	9
E	7	7	0
F	0	28	28
G	13	13	0
H	20	20	0
I	0	28	28
J	23	23	0
K	26	26	0
L	28	28	0
M	0	27	27

Source: Processed Data (2024)

4.4 Calculation of slope value

The increase in cost caused by the first cost slope can be done by calculating the activity cost or acceleration effect using the following formula:

Acceleration cost : $\frac{\text{normal time}}{\text{accelerated time}}$

A preparation work
Normal Time : 2 days
1 Days : 8 Hours
Acceleration time : 10% x 2 = 0,2
Accelerated days = 2 – 0,2 = 1,8 hari

Cost = $\frac{2}{1,8}$ x Rp. 779.625 = Rp. 1.189.953

Table 4. Time and cost of project acceleration Construction School building

No	Activity Item	Prodecessor	Normal Duration	Normal Cost	Acceleration Time	Acceleration Cost
1.	Preparation work	-	2	779.625	1,8	1.189.953
2.	Earthwork and demolition	A	2	6.138.815	1,8	9.369.770
3.	Foundation work	B	3	2.081.346	2,7	2.852.241
4.	Wall work	C	4	15.626.972	4	15.626.972
5.	Concrete work	C	6	52.205.027	5,4	61.872.624
6.	Plastering work	C, D	2	18.262.646	2	18.262.646
7.	Iron work	D, E	7	35.483.131	6,3	41.115.374
8.	Roof covering work	G	3	21.318.176	2,7	29.213.796
9.	Ceiling work	H	2	5.071.140	2	5.071.140
10.	Aluminum work	H	3	10.493.022	2,7	14.379.326
11.	Wood work	J	2	5.256.555	1,8	8.176.863
12.	Key and glass work	K	2	4.497.375	1,8	6.995.916
13	Electrical work	F, L, I	3	2.370.813	3	2.370.813
Amount		33		Rp. 179.584.643	30	RP.216.497.434

Source : Processed Data (2024)

From table 2, it can be determined that the duration required to complete the school building construction project after the project acceleration is 30 days with a total cost of Rp. 216,497,434 from the original duration of 33 days and a total cost of Rp. 179,584,643. After the project acceleration cost is known, the amount of additional costs caused by the acceleration can be determined using the formula:

Cost slope = $\frac{\text{Accelerated Cost} - \text{Normal Cost}}{\text{Normal Time} - \text{Accelerated Time}}$

Cost slope = $\frac{\text{Rp.1.189.953} - \text{Rp.779.625}}{2 - 1,8}$ = Rp. 410.328 per day

Table 5. Recapitulation of cost slope

No	Activity Item	Time Acceleration	Cost Slope	Crash Cost
1.	Preparation work	1,8	230.960	410.328
2.	Earthwork and demolition	1,8	1.794.997	3.230.995
3.	Foundation work	2,7	285.516	770.895
4.	Concrete work	5,4	1.790.296	9.667.597
5.	Iron work	6,3	894.007	5.632.243
6.	Roof covering work	2,7	2.924.303	7.895.620
7.	Aluminum work	2,7	1.439.371	3.886.304
8.	Wood work	1,8	1.622.393	2.920.308
9.	Key and glass work	1,8	1.388.078	2.498.541
Amount				Rp. 36.912.804

Source : Processed Data (2024)

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Based on the table, it can be seen that the cost slope shows changes in additional costs incurred per day for each project work activity carried out with acceleration, namely project work that is on the critical path with a total addition of around Rp. 36,912,804 from the total normal cost.

4.5 Comparison of normal and accelerated time and cost

From the results of the analysis using the CPM method, the accelerated time is obtained which is more optimal in terms of time and cost aspects when compared to normal time. It can be seen in table 6.

Table 6. Comparison of normal time and cost with acceleration

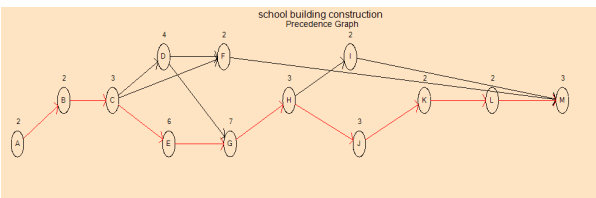
Information	Critical Path Method (CPM)	
	Normal Time	Accelerated Time
Completion time	33 days	30 days
Project completion cost	Rp. 179.584.643	Rp. 216.497.434

Source: Processed Data (2024)

From table 6, it can be concluded that with the acceleration carried out on the work on the critical path, the completion time of the school building construction project is faster than the previous normal time, which is 30 and from the costs incurred, the cost of completing the school building construction project is greater than the normal time cost, which is Rp. 216,497,434.

Completion time of the School Building Construction project before acceleration and after acceleration is proven by the network image processed using POM QM for Windows software, can be seen in the image 3 and 4.

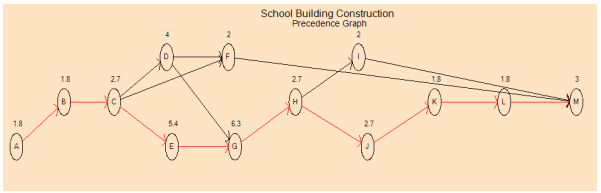
Figure 3. Network diagram before acceleration time



Source: Processed Data (2024)

Figure 4 is a picture of the work network before acceleration which shows the total amount of activity time of 33 days, with the note that activities with Codes (D, F and I) can be done simultaneously with work (E, G and J) so they are not recalculated.

Figure 4. Network diagram after



Source : Processed Data (2024)

Figure 4 is a picture of the work network after acceleration which shows the total amount of activity time of 30 days or exactly 1 month.

4.6 Discussion

Project scheduling using the CPM method can be applied to construction projects on school buildings as stated by Septiawan (2020) that CPM is applied to construction projects to ensure the efficiency of the project work schedule and resource management. Analysis of the scheduling of the School Building Construction project by CV Prima Karya based on schedule data and analysis using the CPM method obtained information that the work network diagram that had been prepared illustrated a series of activities for the School Building Construction project, the critical path could be determined.

The critical path is the path with the longest series of activities and the slack value in the activity is equal to 0 (Agyei 2015). So the work on this critical path is A (Preparation work) B (Earthwork and demolition), C (Foundation work), E (Concrete work), G (Iron work), H (Roof covering work), J (Aluminum work), K (Woodwork), and L (Key and glass work), because it has the longest project completion duration compared to other paths. Therefore, work on the critical path must be prioritized and can be completed on time to avoid delays. As stated by Heravi and Eslamdoost (2021) that the CPM method is an effective method in managing the risk of delays

in infrastructure projects in developing countries.

Related research that is in line with the application of CPM is a study conducted by Sari, (2021) that the application of CPM to the IT Optical Distribution Point infrastructure development project can help analyze optimal time and estimate the overall cost of the project. In this study, the companies participating in the project have not used the project scheduling method in the process of completing the project work, so there are still delays in completion. However, by applying the CPM method, the critical path can be determined in a series of activities so that the project can be completed on time and effectively. Thus, it can be concluded that the application of CPM in a project can help the Company minimize delays in completing the project work time.

5. Closing

5.1 Conclusion

From the application of the critical path method (CPM) analyzed by the author on the sadechool building construction project, it can be concluded that there are several jobs that are passed through the critical path. Where all jobs passed through the critical path must be completed according to the time that has been set to avoid delays in project completion and not interfere with other jobs. The time required to carry out the construction of the school building was accelerated to 30 with a cost of Rp. 216,497,434

5.2 Suggestion

Therefore, to improve efficiency in project management, it is recommended for the Company to work overtime on work that is on the critical path and the Company can apply the critical path method (CPM) to reduce the risk of delays and optimize costs and completion time. For future research, it is recommended to try other project management methods such as PERT Charts, Gantt Charts, and Event Chain Diagrams and continue with the S curve for better research results.

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