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Implementation of The Critical Path Method for Project Scheduling Using Python (Case Study: Construction of The Official Residence for The Commander and Deputy Commander of Company C, Morut Pioneer Battalion, Central Sulawesi Regional Police)

Grace C.C. Lohonauman*, Steenie E. Wallah, Grace Y. Malingkas
Universitas Sam Ratulangi Manado, Indonesia
Email: lohonaumangrace@gmail.com*

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Abstract

Construction project management quality is the primary goal of every project executor. The Critical Path Method (CPM) enables efficient project scheduling by identifying critical activities and optimizing work sequences. This study aims to schedule the construction of the official residence for the Commander and Deputy Commander of Company C, Morut Pioneer Battalion, Central Sulawesi Regional Police, using CPM integrated with Python programming. Data were collected from project schedule documents comprising 28 activities with an initial planned duration of 180 days. Using CPM analysis with Python's NetworkX library, forward and backward pass calculations were performed to determine ES, EF, LS, LF, and total float values for each activity. The results show that the project duration can be optimized from 180 days to 127 days, achieving a time saving of 53 days (29.44%). Activities with a total float value of zero constitute the critical path, while non-critical activities retain scheduling flexibility. This study demonstrates that CPM integrated with Python effectively supports project scheduling decisions, resource allocation, and timeline control in construction project management.

INTRODUCTION

Quality construction project management is the primary goal of every project executor. A construction project is considered successful if it can be completed within the planned schedule and budget, meaning the project has been realized perfectly (Goshu et al., 2024; Zahoor & Ali, 2023). Achieving perfect execution in construction projects will certainly provide many benefits for both the executing company and the client (Ochoa Pacheco et al., 2023). However, in reality, achieving perfect execution is very difficult due to the many obstacles encountered during the implementation process (Wawak et al., 2020; Abdelhameed et al., 2026).

The success or failure of a project is usually caused by the lack of an effective work activity plan, resulting in delays or cost overruns during project implementation (Ramadhan & Waty, 2025;

Doe, 2025; Sovacool & Ryu, 2025). Project scheduling serves to show the interrelationship between each activity in the project, as every activity is closely related to the overall project; this scheduling helps determine the sequence of work that must be completed first (Gómez-Cabrera et al., 2025; Rosłon, 2022). Levin and Kirkpatrick (1972) stated that the Critical Path Method (CPM) is the most commonly used method for planning and supervising projects. This method is the most widely used system among various network-based systems (Kadang et al., 2024; Seki et al., 2025). The Critical Path Method enables efficient scheduling by identifying the critical path and the most important activities to complete the project on time (Shah & Chandragade, 2023).

In line with current technological developments, information and communication technology is one of the fields whose impact can be felt through the assistance of software programs created to facilitate data processing and numerical analysis (Castro et al., 2023). Python is a high-level, versatile, and easy-to-learn programming language for software development. Python can be easily integrated with existing software or used to develop customized solutions. Python is a highly flexible programming language that allows the CPM Method to be integrated into existing project management systems (Raranta et al., 2025).

The integration of Python in the CPM Method can help increase productivity and efficiency in project scheduling, as Python provides various data visualization libraries such as Matplotlib and Seaborn (Ahmed 2024; Aloorravi 2024; Ezechukwu 2022). Using these libraries helps create graphs and diagrams, assisting in clearly visualizing project schedules, critical paths, and other activities. With more sophisticated analysis and more accurate modeling, project management decisions can be made more quickly and effectively to reduce overall time and cost (Haque et al. 2025; Nabeel 2024; Tanim et al. 2025).

Based on the background described above, the research problem to be addressed is: how to schedule the construction of the official residence for the Commander and Deputy Commander of Company C, Morut Pioneer Battalion, Central Sulawesi Regional Police using the CPM Method, and how to determine the critical path from that schedule using Python.

Based on the research problem stated above, the objective of this study is to determine the scheduling of the construction of the official residence for the Commander and Deputy Commander of Company C, Morut Pioneer Battalion, Central Sulawesi Regional Police using the CPM Method, and to obtain the critical path from that schedule using Python.

METHOD

Research Location

In this study, the author conducted research on the construction project of the Official Residence for the Commander/Deputy Commander of Company C, Morut Pioneer Battalion, Central Sulawesi Regional Police. The location is shown in the figure below:

Figure 1. Research Location

Research Stages

Literature Study

A literature review is an important step in writing this report as it provides a solid knowledge base and supports the arguments made. The following literature studies were required:

a. Study on building construction
b. Study on project management
c. Study on the CPM Method
d. Study on Python

Data Collection

In this study, the author used data collection techniques divided into two types:

1. Primary Data
   Primary data collected by the author consists of project schedule documents and the S-curve.
2. Secondary Data
   Secondary data refers to supporting data such as literature or materials related to the Critical Path Method and Python relevant to the author's research, including books, lecture notes, journals, and papers related to the research.

Data Analysis Using CPM Method and Determining the Critical Path

1. Identifying Each Activity

   From the divided structure, the first step is to create a complete list of project activities. This information will serve as the basis for adding details on the sequence and duration of each activity in the next step.
2. Arranging Activity Sequence

   Each activity is interrelated with one another. By listing the relationships between these activities, the author can form a CPM (Critical Path Method) network diagram.
3. Creating a Network Diagram

   Once the relationships between activities have been established, the next step is to create a Network Diagram. In this study, the author used the Activity on Arrow method to represent the relationships between activities.
4. Project Completion Time Estimation

   The author obtained the estimated project completion time from the initial plan prepared by the company.
5. Critical Path Identification

   The critical path can be determined by identifying activities with a float/slack value of 0. Total Float is calculated using LS - ES or LF - EF. The values of ES and EF are calculated using the forward pass formula EF = ES + D, while the values of LS and LF are calculated using the backward pass formula LS = LF - D.

Data Analysis Using Python and Determining the Critical Path

1. Identifying Each Activity

   From the divided structure, the first step is to create a complete list of project activities. This information will serve as the basis for adding details on the sequence and duration of each activity in the next step.
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   The author obtained the estimated project completion time from the initial plan prepared by the company.

Python Flowchart

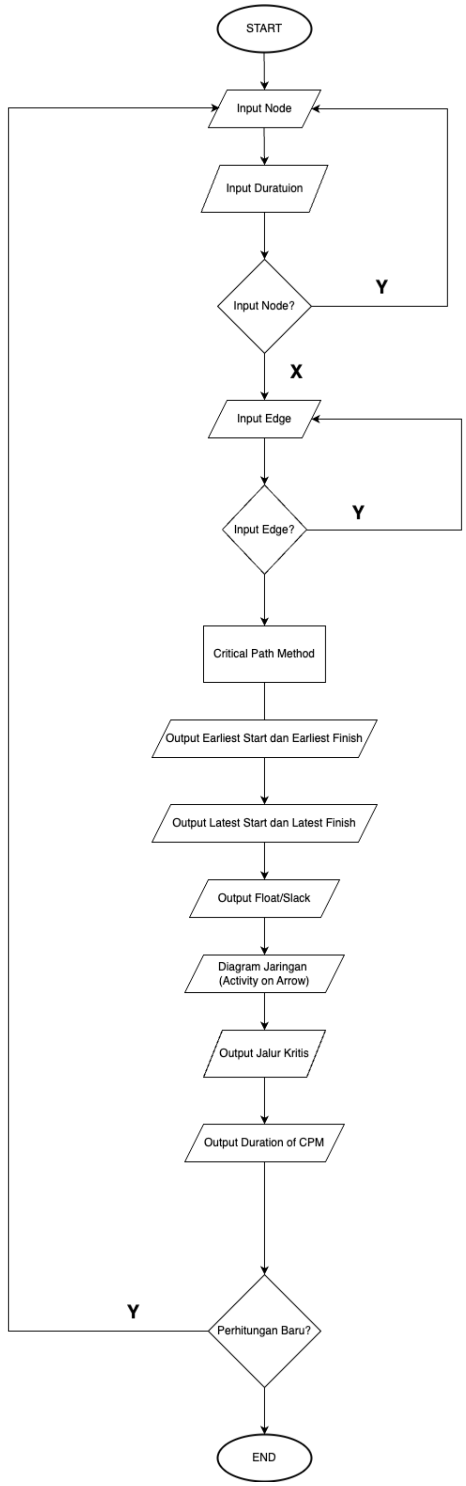

Figure 2. Python Flowchart

RESULTS AND DISCUSSION

The Critical Path Method (CPM) is fundamentally used to identify the sequence of project activities, establish a work network, input durations for each activity, and determine the relationships between tasks. Through this process, forward pass and backward pass calculations are performed to identify the critical path and estimate the total construction duration of this official residence.

Project Scheduling Data

In the process of preparing the project schedule, data for each activity must be detailed so that the completion time for each task can be accurately determined. The work durations for the construction project of the Official Residence DANKI WADANKI Yon C are presented in the following S-curve table.

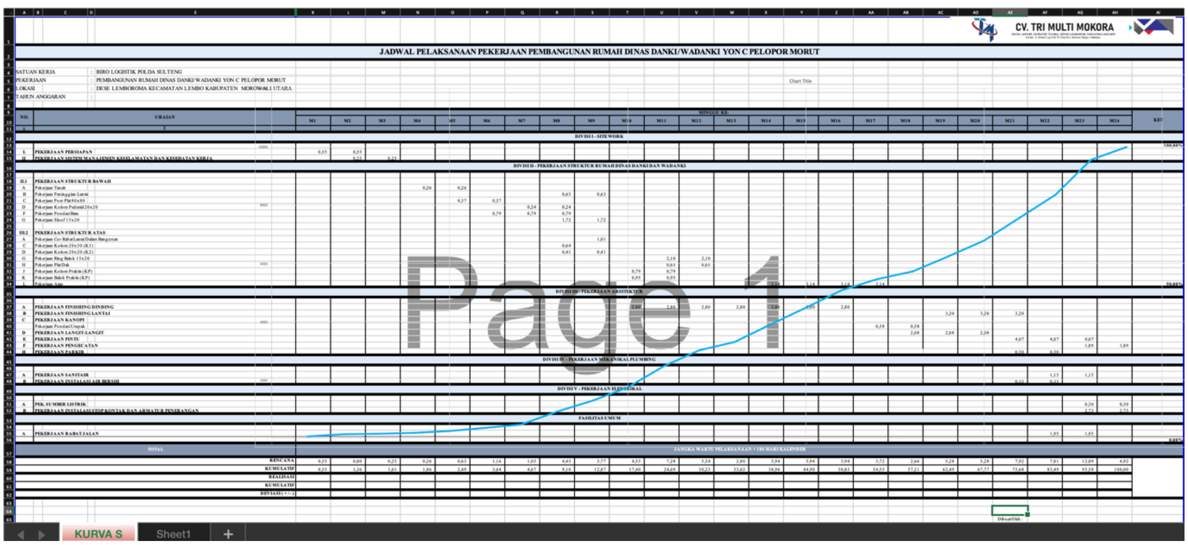

Figure 3. Scheduling Data

Table 1. Duration and Activities

No.	Activity	Duration (days)
1.	Preparatory Work	7
2.	Occupational Health and Safety (K3)	3
3.	Earthwork	10
4.	Floor Elevation Work	6
5.	Pile Cap Work 80x80	5
6.	Pedestal Column Work 20x20	5
7.	Stone Foundation Work	10
8.	Grade Beam Work 15x20	8
9.	Floor Lean Concrete Work	5
10.	Column Work 20x30	10
11.	Column Work 20x20	8
12.	Ring Beam Work 15x20	8
13.	Roof Slab Work	8
14.	Practical Column Work	5

15.	Practical Beam Work	5
16.	Roofing Work	12
17.	Wall Finishing	10
18.	Floor Finishing	8
19.	Pedestal Foundation Work	5
20.	Ceiling (Plafond)	8
21.	Door Work	5
22.	Painting Work	5
23.	Parking Area Work	4
24.	Water Sanitation Work	4
25.	Water Installation	4
26.	Electrical Power Source Work	4
27.	Electrical Outlet Installation	4
28.	Road Concrete Work	4
	Total Duration	180

Activity Relationship Identification

All activities or each work item is assigned a code, and after coding, the next step is to determine the interrelationships between tasks. This process is carried out to facilitate activity identification and is important for understanding the execution sequence, as well as supporting the critical path determination process in the subsequent analysis.

Table 2. Activity Codes

No.	Activity	Activity Code
1.	Preparatory Work	A
2.	Occupational Health and Safety (K3)	B
3.	Earthwork	C
4.	Floor Elevation Work	D
5.	Pile Cap Work 80x80	E
6.	Pedestal Column Work 20x20	F
7.	Stone Foundation Work	G
8.	Grade Beam Work 15x20	H
9.	Floor Lean Concrete Work	I
10.	Column Work 20x30	J
11.	Column Work 20x20	K
12.	Ring Beam Work 15x20	L
13.	Roof Slab Work	M
14.	Practical Column Work	N
15.	Practical Beam Work	O
16.	Roofing Work	P
17.	Wall Finishing	Q
18.	Floor Finishing	R
19.	Pedestal Foundation Work	S
20.	Ceiling (Plafond)	T
21.	Door Work	U
22.	Painting Work	V
23.	Parking Area Work	W
24.	Water Sanitation Work	X

25.	Water Installation	Y
26.	Electrical Power Source Work	Z
27.	Electrical Outlet Installation	AA
28.	Road Concrete Work	AB

Setelah melakukan pengkodean dari setiap kegiatan berikutnya akan diklasifikasikan berdasarkan hubungan dari setiap kegiatan yang ada.

Tabel 3. Analisa Ketergantungan Antar Kegiatan

No.	Activity	Activity Code	Duration (days)	Next Activity Code
1.	Preparatory Work	A	7	B
2.	Occupational Health and Safety (K3)	B	3	C
3.	Earthwork	C	10	D,S
4.	Floor Elevation Work	D	6	E
5.	Pile Cap Work 80x80	E	5	F,G
6.	Pedestal Column Work 20x20	F	5	H
7.	Stone Foundation Work	G	10	H
8.	Grade Beam Work 15x20	H	8	I,J,X,Z
9.	Floor Lean Concrete Work	I	5	R
10.	Column Work 20x30	J	10	K
11.	Column Work 20x20	K	8	L
12.	Ring Beam Work 15x20	L	8	M
13.	Roof Slab Work	M	8	N
14.	Practical Column Work	N	5	O
15.	Practical Beam Work	O	5	P
16.	Roofing Work	P	12	Q,T
17.	Wall Finishing	Q	10	R,U,Y,AA,V
18.	Floor Finishing	R	8	W
19.	Pedestal Foundation Work	S	5	AB
20.	Ceiling (Plafond)	T	8	V
21.	Door Work	U	5	V
22.	Painting Work	V	5	FINISH
23.	Parking Area Work	W	4	AB
24.	Water Sanitation Work	X	4	Y
25.	Water Installation	Y	4	FINISH
26.	Electrical Power Source Work	Z	4	AA
27.	Electrical Outlet Installation	AA	4	FINISH
28.	Road Concrete Work	AB	4	FINISH
	Total Days		180	

Forward Pass Calculation (ES and EF)

The forward pass stage aims to determine the earliest time an activity can start (Early Start/ES) and the earliest time that activity can be completed (Early Finish/EF). The formulas used are:

- ES(i) = EF aktivitas pendahulu yang terbesar
- EF(i) = ES(i) + Durasi(i)

The results of this calculation determine the minimum time required to complete the project if all work proceeds without interruption.

Table 4. Forward Pass Calculation Table

No.	Activity	Duration (days)	ES	EF
1.	Preparatory Work	7	0	7
2.	Occupational Health and Safety (K3)	3	7	10
3.	Earthwork	10	10	20
4.	Floor Elevation Work	6	20	26
5.	Pile Cap Work 80x80	5	26	31
6.	Pedestal Column Work 20x20	5	31	36
7.	Stone Foundation Work	10	31	41
8.	Grade Beam Work 15x20	8	41	49
9.	Floor Lean Concrete Work	5	49	54
10.	Column Work 20x30	10	49	59
11.	Column Work 20x20	8	59	67
12.	Ring Beam Work 15x20	8	67	75
13.	Roof Slab Work	8	75	83
14.	Practical Column Work	5	83	88
15.	Practical Beam Work	5	88	93
16.	Roofing Work	12	93	105
17.	Wall Finishing	10	105	115
18.	Floor Finishing	8	115	123
19.	Pedestal Foundation Work	5	20	25
20.	Ceiling (Plafond)	8	105	113
21.	Door Work	5	115	120
22.	Painting Work	5	120	125
23.	Parking Area Work	4	123	127
24.	Water Sanitation Work	4	49	53
25.	Water Installation	4	115	119
26.	Electrical Power Source Work	4	49	53
27.	Electrical Outlet Installation	4	115	119
28.	Road Concrete Work	4	127	131

Backward Pass Calculation (LS and LF)

The backward pass is used to calculate the latest time a task may start (Late Start/LS) and the latest time it may be completed (Late Finish/LF) without delaying the project completion. The formulas used are:

- LS (Late Start) = The latest time an activity may start without delaying the project
- LF (Late Finish) = LS + duration

Table 5. Backward Pass Calculation Table (LS and LF)

No.	Activity	Duration (days)	LS	LF
1.	Preparatory Work	7	0	7
2.	Occupational Health and Safety (K3)	3	7	10
3.	Earthwork	10	10	20
4.	Floor Elevation Work	6	20	26
5.	Pile Cap Work 80x80	5	26	31
6.	Pedestal Column Work 20x20	5	31	36
7.	Stone Foundation Work	10	31	41
8.	Grade Beam Work 15x20	8	41	49
9.	Floor Lean Concrete Work	5	49	54
10.	Column Work 20x30	10	49	59
11.	Column Work 20x20	8	59	67
12.	Ring Beam Work 15x20	8	67	75
13.	Roof Slab Work	8	75	83
14.	Practical Column Work	5	83	88
15.	Practical Beam Work	5	88	93
16.	Roofing Work	12	93	105
17.	Wall Finishing	10	105	115
18.	Floor Finishing	8	115	123
19.	Pedestal Foundation Work	5	20	25
20.	Ceiling (Plafond)	8	105	113
21.	Door Work	5	115	120
22.	Painting Work	5	120	125
23.	Parking Area Work	4	123	127
24.	Water Sanitation Work	4	49	53
25.	Water Installation	4	115	119
26.	Electrical Power Source Work	4	49	53
27.	Electrical Outlet Installation	4	115	119
28.	Road Concrete Work	4	127	131

Total Float Calculation

Total float represents the amount of time an activity can be delayed before it causes a delay to the overall project. Activities with a total float value of zero (0) are categorised as critical activities, meaning that even the slightest delay in these activities will directly delay the project completion time.

Mathematically, total float can be calculated using two approaches that yield the same result:

$$\text{Total Float (TF)} = LS - ES$$

or

$$\text{Total Float (TF)} = LF - EF$$

In total float, activities with a total float value of zero (0) are referred to as critical activities. This means these activities have no tolerance, so any delay, even of just one day, will directly impact the overall project schedule. These activities form the critical path.

The following shows the total float calculations as presented in the table below:

CPM Calculation Using Python

Algorithm

The steps for composing the CPM analysis algorithm through Python are:

1. Entering the duration of each activity
2. Entering the relationships between activities.
3. Generating output in the form of the critical path and total project duration.
4. Drawing the work network diagram.
5. Calculating ES, EF, LS, LF, and total float.
6. Displaying the complete CPM diagram with the critical path.

Python Program

This section presents the Python script used to:

- Building a work network based on a directed graph,
- Calculating the critical path using the NetworkX library,
- Calculating ES, EF, LS, LF, and slack,
- Displaying the CPM diagram in visual form,
- Determining the total duration of the critical path.

CONCLUSION

Based on the results of the project scheduling analysis using the Critical Path Method (CPM) for the construction project of the Official Residence DANKI WADANKI Yon C, it was found that the originally planned project duration of 180 days can be optimised to 131 days. This represents a time saving of 49 days, or 27,22%, compared to the initial schedule.

The analysis results show that the CPM method successfully identified the Critical Path, which is the sequence of activities with a Total Float (TF) = 0, meaning they have no scheduling flexibility. Any delay in any activity on the critical path will result in a delay to the overall project completion.

Meanwhile, several activities such as Pile Cap Work 80x80 (E), Stone Foundation Work (G), Column Work 20x30 (J), Ring Beam Work 15x20 (L), Roof Slab Work (M), Door Work (U), Parking Area Work (W), Water Sanitation Work (X), Water Installation (Y), and Electrical Outlet Installation (AA) have float values, meaning their execution still retains scheduling flexibility without affecting the project completion duration, as long as the available float is not exceeded.

Overall, the application of the Critical Path Method (CPM) has been proven to increase the effectiveness of project planning and time control. By optimising the work execution sequence and utilising activities that can be performed in parallel, the project duration was successfully reduced from 180 days to 131 days, yielding a time efficiency of 27,22%, or a saving of 49 days. These results demonstrate that the CPM method is an effective tool for supporting decision-making, resource allocation, and schedule control, enabling the project to be completed more efficiently and on time.

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