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PROJECT SCHEDULING ANALYSIS USING CPM AND PERT IN THE CONSTRUCTION OF NAKULA SHOP HOUSES

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Abstract. The success of a project is often caused by the lack of planning and control of a project that is less effective, therefore project completion often experiences delays and costs are increasing. In the practice, the duration of project completion is limited in accordance with the mutually agreed upon agreement so that it is necessary to anticipate changes in conditions that will occur. Project management is needed to manage projects to be more optimal by utilizing CPM and PERT. By comparing CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) in project scheduling on the construction of Ruko Nakula carried out by PT Artha Wijaya Utama, CPM has a faster project completion duration than PERT. The duration required to finish a project with CPM is 49 weeks while PERT requires a duration of 52 weeks.
Keyword: Project, CPM, PERT

INTRODUCTION

To ensure a project is executed according to plan, project management is essential for smooth implementation. The success or failure of a project depends on effective planning, scheduling, and project control (Caesaron et al., 2017).

In construction projects, project management plays a crucial role in ensuring proper planning and execution, leading to optimal project outcomes. In the construction of Nakula Shop Houses, PT XYZ aims to avoid project delays, as delays may result in penalties that could cause financial losses for the company.

Project scheduling involves determining the time frame within which project activities must be completed according to the established schedule. Project scheduling helps identify interrelated activities that must be performed in a specific sequence before the overall task can be completed (Taha, 1996). These activities are logically connected, meaning that one activity cannot begin until its predecessor is completed. Additionally, project scheduling facilitates the estimation of project completion time. This study will conduct a project scheduling analysis using the CPM and PERT methods.

CPM, or the Critical Path Method, is a project scheduling technique based on non-probabilistic time estimates, whereas PERT, or the Program Evaluation and Review Technique, incorporates probabilistic time estimates (Taha, 1996). The project scheduling results from these two methods will be compared to identify the most effective method for achieving the fastest project completion. This analysis aims to prevent delays in the completion of the Nakula Shop Houses project by PT XYZ.

RESEARCH METHODOLOGY

The data source used in this research consists of secondary data obtained from PT XYZ, specifically the time schedule for the construction of the Nakula Shop Houses in 2016–2017. The variables used in this study include the project's optimal time as the dependent variable, while the independent variables consist of project duration and dependency relationships. To estimate the project duration, the CPM and PERT methods were utilized, incorporating network diagrams or arrow diagrams. The steps for project scheduling using CPM and PERT in the case of estimating project completion time are described as follows (Maharesi et al., 2002):

1. Detailing Activities and Their Durations
    - In PERT, it is necessary to estimate the shortest time (symbolized by a), the longest time (b), and the most likely time (m). Using these three time estimates, the distribution of an activity's duration can be assumed to follow a normal distribution.
2. Establishing Activity Relationships
    - Determine the relationships between activities and identify which activities precede subsequent ones.
3. Creating an Arrow Diagram
    - Develop a network arrow diagram for the project, ensuring the activity relationships are properly represented.
4. Determining Durations
    - In CPM, project duration is calculated using the most likely time. For PERT, the mean and variance of each activity's duration must be computed.
5. Calculating Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), and Latest Finish (LF)
    - These values are determined to identify the timing of each activity in the schedule.
6. Calculating Slack Time
    - Slack is calculated as LS - ES or LF - EF to determine the flexibility of each activity.
7. Identifying the Critical Path
    - The critical path is identified by observing the slack values. If slack equals zero, the activity is critical. If slack is not equal to zero, the activity is non-critical.
8. Estimating Project Completion Time
    - Once the critical path is identified, the estimated project completion time is calculated by summing the durations of all activities on the critical path.
    - For PERT, the probability of project completion can be calculated based on the estimated durations.

RESULTS AND DISCUSSION

The first step in conducting project scheduling is to outline activities or activities with

a predetermined duration. In this study, the arrangement of work activities is based on data from the Nakula Shophouse development project carried out by XYZ as seen in Table 1.

Table 1. Job Description and Duration of Work

No	Job description	Job Symbol	Duration (Sunday)
1	Preparatory work	A	1
2	Excavation and Backfill Work	B	2
3	Foundation Couple Work	C	3
4	Concrete Structure Work	D	9
5	Wall Work, Plastering and Rendering	E	8
6	Roof and Roof Work (Light Steel)	F	3
7	Ceiling Finishing Work	G	5
8	Floor and Wall Finishing Work	H	5
9	Door and Window Frame Work	I	4
10	Front Finishing Work-Loster-Glass Block & Trellis & Railing	J	8
11	Painting and Finishing Work	K	3
12	Electrical Work	L	9
13	Sanitary Work	M	4

CPM

After knowing the job description and its duration, then determine the relationship between jobs and then determine the critical path. The critical path in the CPM method is a series of jobs where there should be no delays in the series of jobs that will result in delays in project completion.

The determination of the critical path is preceded by a forward calculation to determine the Early Start (ES) Early Finish (EF) and a backward calculation to determine the Latest Start (LS) Latest Finish (LF). From the forward and backward calculations, we can determine the critical path by calculating the float/slack which is the time when work can be postponed without affecting the overall project completion time.

Determining Relationships Between Jobs

Determining the relationship between jobs is the process of arranging a job according to its predecessor's job, this means that a job cannot be continued to the next job before the previous job has been completed. After determining the relationship between these jobs, a network diagram can then be drawn containing the job path and the sequence of jobs that will be carried out during the implementation of the project.

Table 2. Relationship of Each Job

No	Job description	Job Symbol	Work Predecessor	Duration (Sunday)
1	Preparatory work	A	-	1
2	Excavation and Backfill Work	B	A	2
3	Foundation Couple Work	C	B	3
4	Concrete Structure Work	D	C	9
5	Wall Work, Plastering and Rendering	E	C, D	8
6	Roof and Roof Work (Light Steel)	F	D, E	3
7	Ceiling Finishing Work	G	F	5
8	Floor and Wall Finishing Work	H	G	5
9	Door and Window Frame Work	I	E, F	4
10	Front Finishing Work-Loster-Glass Block & Trellis & Railing	J	I	8
11	Painting and Finishing Work	K	H,J	3
12	Electrical Work	L	H	9
13	Sanitary Work	M	K, L	4

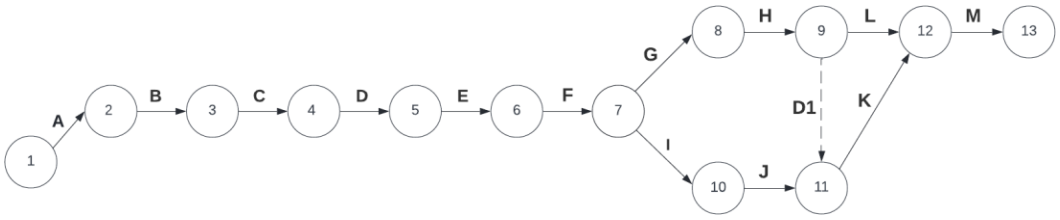


Figure 1. Network Planning Diagram 1

Based on Table 2. obtained a network planning diagram as in Figure 1. where the number in the circle is the activity or job number, the arrow shows the job path according to the predecessor activity, and there is D1 or Dummy 1 which is a job that does not use time or resources. Dummy appears because there should not be two activities that can be identified with the same arrow event and head event(Taha, 1996), in the diagram you can see the dotted arrow connecting activities 9 and 11.

CPM Calculation

The critical path is a chain of critical activities that connects the initial and final events of an arrow diagram.(Taha, 1996).

CPM calculation. using POM QM software for windows 5 obtained output results as in Table 3. It can be determined that critical activities are activities that have a slack value = 0.

Table 3. CPM calculation

No	Job Symbol	Duration (Sunday)	ICE	EF	LS	LF	Slack	Critical path
1	A	1	0	1	0	1	0	Yes
2	B	2	1	3	1	3	0	Yes
3	C	3	3	6	3	6	0	Yes
4	D	9	6	15	6	15	0	Yes
5	E	8	15	23	15	23	0	Yes
6	F	3	23	26	23	26	0	Yes
7	G	5	26	31	26	31	0	Yes
8	H	5	31	36	31	36	0	Yes
9	I	4	26	30	37	34	11	No
10	J	8	30	38	41	49	11	No
11	K	3	36	39	42	45	6	No
12	L	9	36	45	36	45	0	Yes
13	M	4	45	49	45	49	0	Yes

Data sources processed

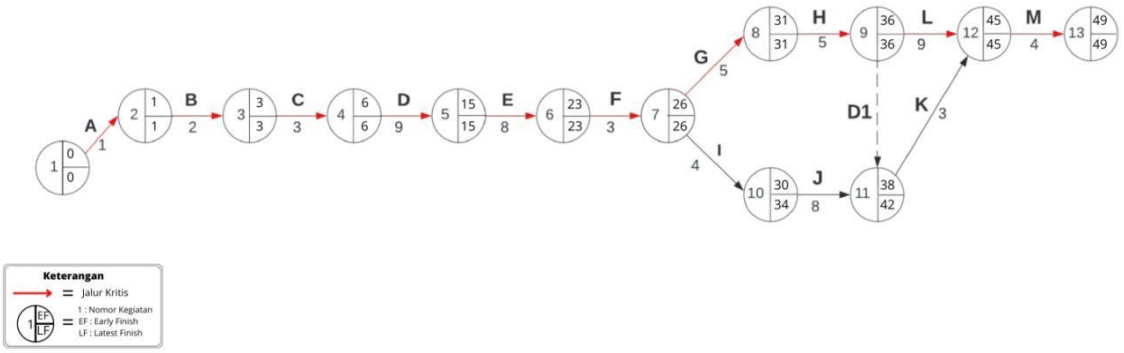


Figure 2. Critical Path Diagram

The calculation results in CPM Table 3. obtained a critical path which is depicted in the diagram with a red arrow as in Figure 2. A series of work activities included in the critical path are on paths A, B, C, D, E, F, G, H, L, M. The critical jobs are Preparation Work, Excavation and Backfill Work, Foundation Masonry Work, Concrete Structure Work, Wall Work, Plastering and Cementing, Roof and Roof Work (Light Steel), Ceiling Finishing Work, Floor and Wall Finishing Work, Painting and Finishing Work, Electrical Work, and Sanitary Work. Estimated project completion time with CPM by adding up the duration of each critical job. Estimated project completion time using CPM.$= 1 + 2 + 3 + 9 + 8 + 3 + 5 + 5 + 3 + 9 + 4 = 49$ minggu

PERT

Time scheduling with PERT is a time estimate using the concept of "probability" with three elements of time estimation. The three time estimates are a (optimistic time), m (realistic time), and b (pessimistic time). After determining the three time estimates, the optimal time can then be calculated.

Because PERT uses the concept of probability, S (standard deviation) and V (variance) can be determined, which are useful for determining how big the chance is that a project can be completed according to the estimated time calculated using PERT.

Table 4. Job Description, Relationships Between Jobs and Job Duration

No	Job description	Job Symbol	Work Predecessor	Duration (Sunday)		
				a	m	b
1	Preparatory work	A	-	1	1	2
2	Excavation and Backfill Work	B	A	2	2	5
3	Foundation Couple Work	C	B	2	3	4
4	Concrete Structure Work	D	C	7	9	11
5	Wall Work, Plastering and Rendering	E	C, D	7	8	9
6	Roof and Roof Work (Light Steel)	F	D, E	3	3	7
7	Ceiling Finishing Work	G	F	3	5	7
8	Floor and Wall Finishing Work	H	G	4	5	6
9	Door and Window Frame Work	I	E, F	4	4	6
10	Front Finishing Work-Loster-Glass Block & Trellis & Railing	J	I	7	8	9
11	Painting and Finishing Work	K	H,J	3	3	4
12	Electrical Work	L	H	7	9	10
13	Sanitary Work	M	K, L	4	4	7

Data sources processed

PERT Calculation

PERT calculations using POM QM software for Windows 5 were obtained results as in Table 4. It can be seen that there is S (standard deviation) and V (variance) of each job. A job that is a critical job is a job that has a slack value = 0.

Table 5. PERT calculation

No	Job Symbol	Duration Optimal	ICE	EF	LS	LF	Slack	Track Critical	S	V
1	A	1	0	1	0	1	0	Yes	0.17	0.03
2	B	3	1	4	1	4	0	Yes	0.50	0.25
3	C	3	4	7	4	7	0	Yes	0.33	0.11
4	D	9	7	16	7	16	0	Yes	0.67	0.44
5	E	8	16	24	16	24	0	Yes	0.33	0.11
6	F	4	24	28	24	28	0	Yes	0.67	0.44
7	G	5	28	33	28	33	0	Yes	0.67	0.44
8	H	5	33	38	33	38	0	Yes	0.33	0.11
9	I	4	28	32	32	36	4	No	0.33	0.11
10	J	8	32	40	36	44	4	No	0.33	0.11
11	K	3	40	43	44	47	4	No	0.17	0.03

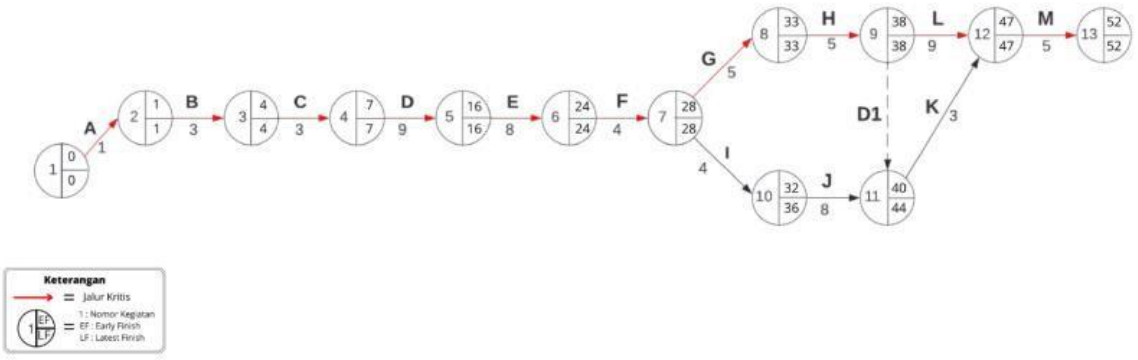


Figure 3. Critical Path Diagram

The calculation results using PERT using software for Windows 5 can be seen in Figure 3. The activities that are critical activities are A, B, C, D, E, F, G, H, L, M. The jobs included in critical jobs are Preparation Work, Excavation and Backfill Work, Foundation Masonry Work, Concrete Structure Work, Wall Work, Plastering and Cementing, Roof and Roof Work (Light Steel), Ceiling Finishing Work, Floor and Wall Finishing Work, Painting and Finishing Work, Electrical Work, and Sanitary Work.

The estimated project completion time can be calculated by summing the duration of all critical tasks. Time estimation using PERT = $1 + 3 + 3 + 9 + 8 + 4 + 5 + 5 + 3 + 9 + 5 = 52$ minggu.

The chance or probability of the project completion time being completed according to the estimate can be calculated by using its critical activities. The calculation is as follows:

$$Z = \frac{Td - Te}{\sqrt{V}}$$

Information :

$Z =$ varian kegiatan

$Td =$scheduled project duration

Te = critical path time duration

Te = critical path time duration

$V =$ Critical path variance

$T(d) = 49$ Weeks

$Te = 52$ Weeks

$$Z = \frac{49 - 52}{\sqrt{2{,}43}}$$

$Z = -1{,}93$

$Z = -1{,}93$

$Z = 0{,}4732$ ($Z -$ table of the normal distribution)

Chance $=1 - 0{,}4732 = 0{,}5268$

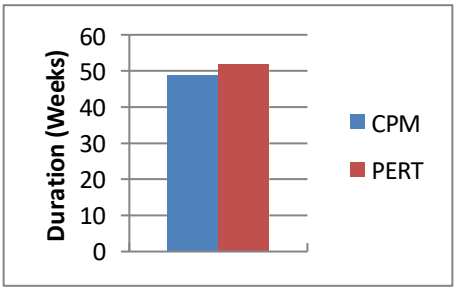
Based on the calculation results above, the probability that the project will be completed according to the estimated time is 52.68%.

A comparison of project completion time using CPM and PERT can be seen in Table 6 and Figure 4.

Table 6. Comparison of Project Completion Time

Description	CPM	PERT	Difference
Duration (weeks)	49	52	3

Figure 4. Comparison of CPM and PERT Duration



CONCLUSION

Based on the results of the discussion, it can be concluded that the completion of the project with CPM time scheduling is 49 weeks while using PERT time scheduling is 52 weeks. Time scheduling with CPM and PERT by considering the desired actual conditions, then time scheduling using CPM has the fastest estimate of project completion so that it can save 3 weeks of time than scheduling using PERT which is certainly more efficient in terms of time and costs required. By scheduling projects with CPM or PERT and representing them in arrow diagrams, companies can find out what work or activities should be prioritized so that there are no delays in project completion which will result in the company being fined. Project scheduling planning must be done carefully so that the estimated time and its application can be in accordance with what is planned.

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