Scheduling of House Development Projects with CPM and PERT Method for Time Efficiency (Case Study: House Type 36)

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Abstract. Network planning is one of the management techniques used to plan and control the implementation of a project, which shows the relationship between activities. The objective of this research is to arrange network planning on house construction project on CV. XYZ and to know the role of network planning in increasing the efficiency of time so that can be obtained the optimal project completion period. This research uses descriptive method, where the data collected by direct observation to the company, interview, and literature study. The result of this research is optimal time planning in project work. Based on the results of the research, it can be concluded that the use of the both methods in scheduling of house construction project gives very significant effect on the completion time of the project. The company's CPM (Critical Path Method) method can complete the project with 131 days, PERT (Program Evaluation Review and Technique) Method takes 136 days. Based on PERT calculation obtained Z= -0.66 or 0,2546 (from normal distribution table), and also obtained the value of probability or probability is 74,54%. This means that the possibility of house construction project activities can be completed on time is high enough. While without using both methods the project completion time takes 173 days. So using the CPM method, the company can save time up to 42 days and has time efficiency by using network planning.

1. Introduction

The construction development in Indonesia is growth. The growth of construction sector has significantly driven by the rapid growth of the domestic property market, private investment, and government spending on infrastructure projects [1]. In the field of construction, scheduling is important because it sets the time and sequence of the various stages, the linkage between one activity to another. Infrastructure development activities includes some activities, starting from planning, execution, along with supervision [2]. Scheduling is structured to become a reference in the implementation of the project as well as the basic for supervision of the project implementation. The primary reason for project scheduling is to ensure that the deadline can be achieved [3]. Although the time planning of a project has been carefully made by consider all the obstacles factors, sometimes the implementation is not represent the plan [4].

In general, techniques in project scheduling can be grouped into two methods, the Gant Chart and Network Planning. Network planning method is one of the management techniques that can be used to assist management in project planning and control. A project schedule network diagram is a graphical representation of the logical relationships, also referred to as dependencies, among the project schedule

activities [5]. There are two basic techniques used in network planning, the Critical Path Method (CPM) and Program Evaluation Review and Technique (PERT). CPM is a time-oriented method that leads to timing and time estimates are deterministic. While PERT is a time oriented method that leads to the determination of the schedule and the time is probabilistic. The object of this research is house type 36. The house type 36 means that the house has an area of 36 m^2. This research uses CPM method because this tool is expected to be used to control the coordination of various activities in a job so that the project can be completed in time. This method is also can help the company in planning, scheduling and supervising projects with more efficient time. So, the objective of this research is how the scheduling of house development project by using CPM and PERT method with more efficient time.

2. Literature Review

Operations management is a form of optimal and comprehensive management that covers several issues including labor, products (services or goods), equipment, machinery and raw material. The management of systems or processes that create goods and/or provide services is called operations management [6]. Some various activity in a company that has a start and finish time called projects. A project includes many temporary activities with limited period of time, specific resource allocations and specific targets. The project is concerned by defining and selecting a task which will give benefit to the company [7].
Project activities is limited by time and cost. Projects are dynamic, non-routine, multi-activity with varying intensity, short cycles, have start and finish point, and fund restrictions. Successful project management requires planning, scheduling and coordinating of interrelated activities. The one of the most significant project management techniques used in planning, scheduling, and controlling a project is network planning [8].

Scheduling is needed to shows the relationship among activites and the whole project and demonstrate realistic cost and time estimates for each activity. Plan, coordination and control has an important role in achieve the goal. There are several techniques in the network planning that can be used. The most widely used techniques of network planning are CPM and PERT.

2.1. CPM (Critical Path Method)

CPM is intended to plan and control a large number of activities that have a complex dependence on design and construction issues. CPM is a project scheduling using time and cost functions. The time estimate used in CPM is only one that represents the normal time [9]. There are several notations used in CPM to identify the critical path:

1. The earliest start (ES), is the earliest time an activity can begin, assuming all predecessors are done.
2. The earliest finish (EF), is the time before an activity can be completed.
3. The last start (LS), is the last time an activity can start, so the completion time of the whole project will not delay.

2.2. PERT (Program Evaluation Review and Technique)

PERT is also known as back research technique. The time estimate used in PERT are three types. The difference between these three types of time is a relative measure of the uncertainty of each activity:

1. The most optimistic time (Wo), is the shortest possible time of completion, if all work goes well.
2. The most pessimistic time (Wp), is the most likely time of completion, account possible delays.
3. The normal time (Wn), is a possible completion time as appropriate.

3. Methodology

The research steps are problem identification, literature study, formulate problem, determine research objectives, perform data collection, data processing and analysis of results using CPM and PERT method, and the last is to make conclusions and suggestions for improvement.

3.1. Data Processing With CPM Method

The project components is identified by break the project scope into activities or activity groups. The next step is rearrange the activities into a chain, so we can know the sequence of activities from the start to the completion of the whole project. Then find the forward calculation with the formula (1) and (2). The forward calculation moves from the initial event to the terminal event. The point is to calculate the fastest event, the fastest commencement and the completion of activities (TE, ES, and EF).

$$TE_{(j)} = ES_{(i,j)} = 0 \quad (1)$$

$$EF_{(i,j)} = ES_{(i,j)} + t_{(i,j)} \quad (2)$$

which:
ES : The fastest start of activity
TE : The fastest event
EF : The fastest completion of activity
T : Time required for an activity

After the forward calculation, then the countdown calculation with the formula (3) and (4). The countdown calculation moves from the event terminal to the initial event. The objective is to calculate the latest event, the latest commencement and completion of activities (TL, LS, and LF).

$$LS_{(i,j)} = LF_{(i)} - t_{(i,j)} \quad (3)$$

$$LF_{(i,j)} = TL\ ;\ TL = TE \quad (4)$$

which:
LS : The latest start of activity
LF : The latest completion of activity
TL : The latest event
t : Time required for an activity

The next step is to find the total float and free float to determine the critical path. Total float (5) is the amount of time at which the completion time of an activity can be postponed without affecting the fastest time of completion of the project as a whole. This step is the critical stage or the longest implementation path, which determines the project completion time. The critical path has a total float equal to zero therefore in determining the critical path, then first calculate the total float of each project activity. Free float (6) is the amount of time that the completion of an activity can be measured without affecting the fastest time from the start of another activity or the fastest event of another on the network.

$$TF = LF - ES - t \quad (5)$$

which:
TF : Total float
LF : The earliest start of activity
ES : The fastest start of activity
t : Time required for an activity

$$FF = EF - ES - t \quad (6)$$

which:
FF : Free Float
EF : The fastest completion of activity
ES : The fastest start of activity
t : Time required for an activity

3.2. Data processing by PERT method

PERT using an arrow diagram to illustrate the project path. In terms of calculation in the same critical activity, critical path or float in PERT is known as slack. The difference between CPM and PERT is very clear in the estimation of the activity period. Three time estimates in PERT:

1. Optimistic time (To), is the possibility of the activities can be completed in a shorter time.
2. The most time arises (Tm), is the estimated time usually occurs under normal circumstances.
3. Pessimistic Time (Tp), is the possibility that activities can be completed in a longer time.

The next step is looking for the average time value by using the formula (7):

$$Mean\ (Te) = \frac{To+4\ Tm+Tp}{6} \tag{7}$$

Then, determine the critical path of PERT network. This is identified by slack calculation, where the activity has the value of free slack (FS) and total slack (TS) = 0. After the critical path is known, then the next step is to calculate the variance (8) and standard deviation (9) for each activity.

$$V\ =\ (Tp - To)/6 \tag{8}$$

$$S = \sqrt{V} \tag{9}$$

In the calculation of settling time using PERT method, the probability of completion construction time is calculated using deviation formula (10).

$$Z = \frac{X - \sum Te\ critical}{\sqrt{\sum V\ critical}} \tag{10}$$

4. Results and Discussion

4.1. CPM Method

Project activities and duration shown in Table 1. Predecessor is activity that precedes current activity.

Table 1. Project activities and duration

No	Activity	Code	Time (Days)	Predecessors
1	Preparatory Works	A	3	-
2	Excavation Works	B	5	A
3	Foundation Works	C	10	B
4	Column Structure Works	D	12	C
5	Sloof Works	E	6	C
6	Wall and Frame Works	F	12	E
7	Roof Trust Works	G	10	D
8	Roof (Ceilings and Tiles) Works	H	17	G
9	Sanitary Works and Electrical Installations	I	20	F, H
10	Plaster Works	J	25	F, H
11	Floor Works	K	18	I
12	Installation Works (Lamps, Glass, Doors, Windows, Switches, Outlets, Locks, Sanitation)	L	15	F
13	Painting Works	M	30	J, K
14	Fencing Works	N	10	L
15	Complementary Works	O	6	M, N

The next step is draw the network diagram as shown in Figure 1.

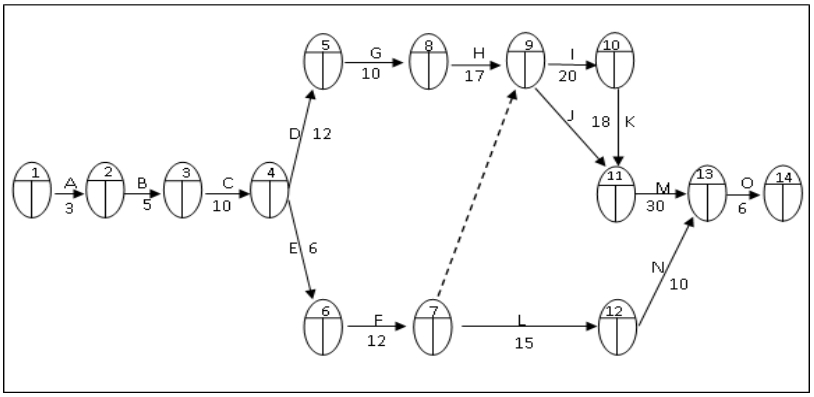

Figure 1. The Network Diagram (CPM Method)

The forward calculation in the completion of a home construction project as follows:
$TE_{(1)}$: since $TE_{(1)}$ is an initial event, then $TE_{(1)}$ is 0.
$TE_{(2)}$: $EF_{(1,2)} = ES_{(1)} + t_{(1,2)} = 0 + 3 = 3$, then $TE_{(2)}$ is 3.

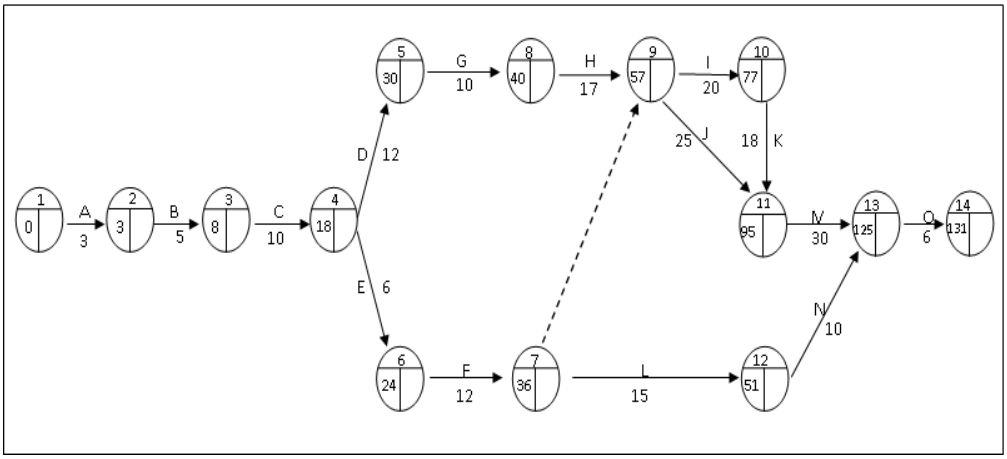

Figure 2. The forward calculation result (CPM Method)

The countdown calculation in the completion of the house building project as follows:
$TL_{(14)}$: since $TL_{(14)}$ is the event terminal, then $TL_{(14)}$ is 131.
$TL_{(13)}$: $LS_{(14,13)} = LF_{(14)} + t_{(14,13)} = 131 - 6 = 125$, then $TL_{(13)}$ is 125.

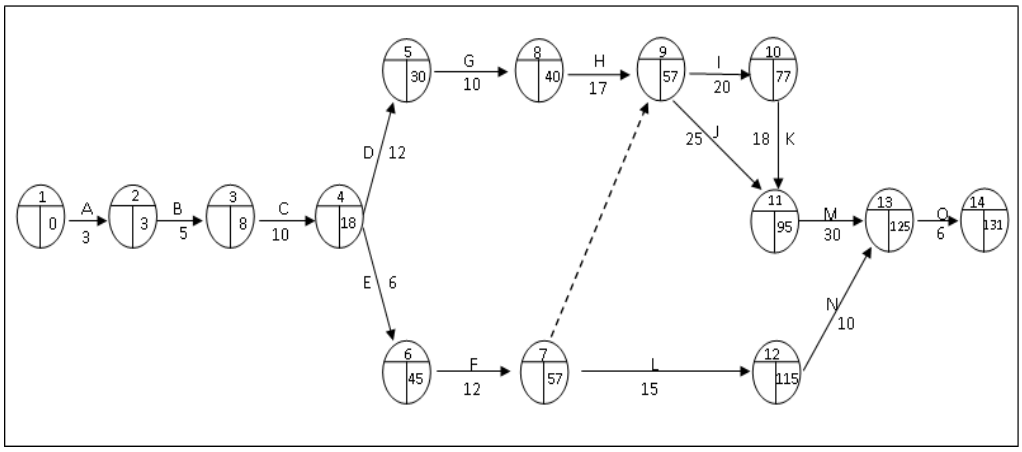

Figure 3. The Countdown Calculation Result (CPM Method)

After the forward and the countdown calculation, the next step is calculate the total float and free float. The results as shown in Table 2.

Table 2. Total float and free float calculation results (CPM Method)

No	Activity	Time (Days)	Before		After		Free Float	Total Float
			Start (ES)	Finish (EF)	Start (ES)	Finish (EF)		
1	A	3	0	3	0	3	0	0*
2	B	5	3	8	3	8	0	0*
3	C	10	8	18	8	18	0	0*
4	D	12	18	30	18	30	0	0*
5	E	6	18	24	18	45	0	21
6	F	12	24	36	45	57	0	21
7	G	10	30	40	30	40	0	0*
8	H	17	40	57	40	57	0	0*
9	I	20	57	77	57	77	0	0*
10	J	25	57	95	57	95	13	13
11	K	18	77	95	77	95	0	0*
12	L	15	36	51	57	115	0	64
13	M	30	95	125	95	125	0	0*
14	N	10	51	125	115	125	64	64
15	O	6	125	131	125	131	0	0*

The sequence of activities of the critical path using the CPM method is A-B-C-D-G-H-I-K-M-O, where the critical path can be seen in the figure below with the completion of the project within 131 days.

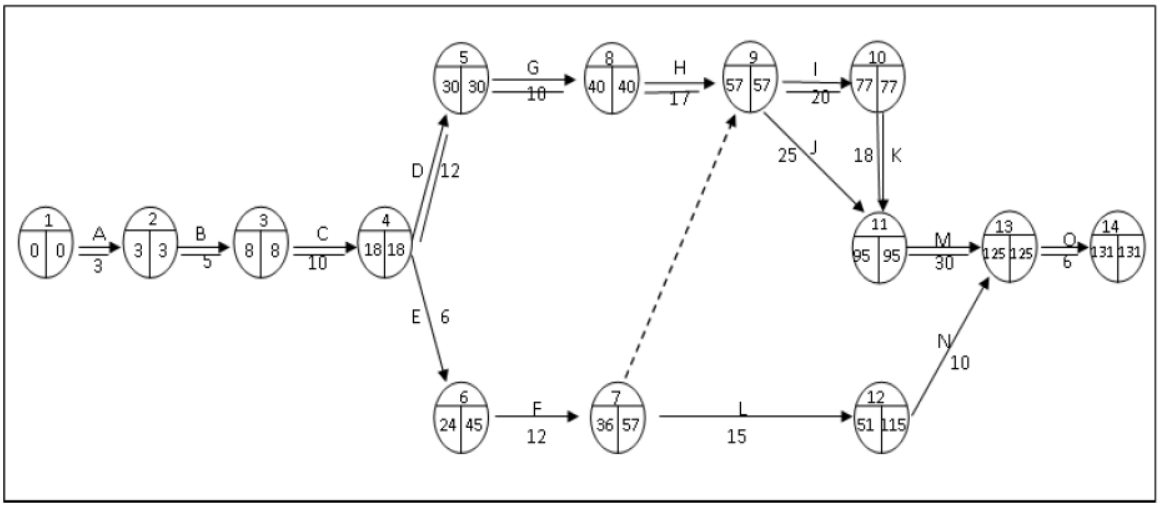

Figure 4. The critical path of the project (CPM Method)

4.2. PERT Method

The data used in PERT method is the primary data from interview and discussion with project team. Average time score is calculate with the formula written before. Then calculate the critical path with PERT by calculate the slack, shown in Table 3. This table is also shows the calculation results of variance and standard deviation.

Table 3. PERT calculation

Activity	Duration			Te	V	S	Before		After		FS	TS	Note
	To	Tm	Tp				TE_i	TE_j	TL_i	TL_j			
A	2	3	4	3	0,11	0,33	0	3	0	3	0	0	*critical
B	3	5	8	5	0,25	0,5	3	8	3	8	0	0	*critical
C	10	10	15	11	0,69	0,83	8	19	8	19	0	0	*critical
D	10	12	17	13	1,36	1,17	19	32	19	32	0	0	*critical
E	5	6	8	6	0,25	0,5	19	25	19	46	0	21	
F	12	12	18	13	1	1	25	38	46	59	0	19	
G	8	10	13	10	0,69	0,83	32	42	32	42	0	0	*critical
H	15	17	20	17	0,69	0,83	42	59	42	59	0	0	*critical
I	20	20	25	21	0,69	0,83	59	80	59	80	0	0	*critical
J	25	25	35	27	2,78	1,67	59	98	59	98	12	12	
K	15	18	23	18	1,78	1,33	80	98	80	98	0	0	*critical
L	13	15	18	15	0,69	0,83	38	53	59	119	0	66	
M	30	30	40	32	2,78	1,67	98	130	98	130	0	0	*critical
N	9	10	14	11	0,69	0,83	53	130	119	130	66	66	
O	6	6	7	6	0,028	0,17	130	136	130	136	0	0	*critical

The network diagram with PERT calculation is shown in Figure 5.

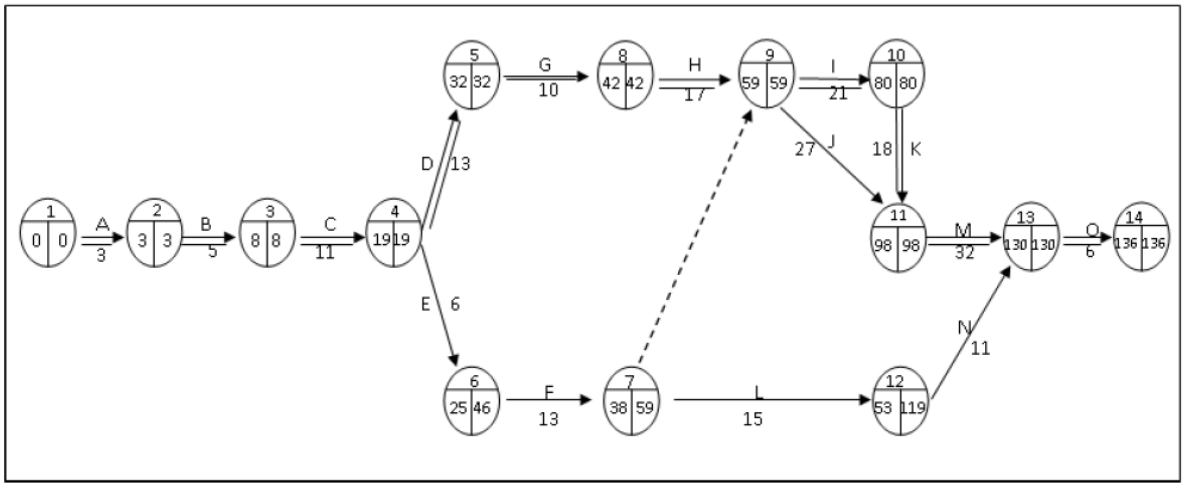

Figure 5. The critical path of the project (PERT Method)

From the calculation of PERT is known the critical activity is A-B-C-D-G-H-I-K-M-O.
T_e critical = 136 days, X = 131 days (assuming CPM completion)
$\sum V$ critical = V (A) + V (B) + V (C) + V (D) + V (G) + V (H) + V (I) + V (K) + V (M) + V (O)
= 0,11 + 0,25 + 0,69 + 1,36 + 0,69 + 0,69 + 0,69 + 1,78 + 2,78 + 0,028 = **9,068**

$$Z = \frac{X - \sum Te\ critical}{\sqrt{\sum V\ critical}} = \frac{131 - 1336}{\sqrt{9{,}068}} = -0{,}66$$

Z = -0.66 ⟶ 0,2546 (from the normal distribution table)

Probability = 1 - 0.2546 = 0.7454
Based on the above calculation result, Z = -0.66, the value of 0.2546 (from the normal distribution table), d the probability or probability of completing the project is 74.54%. This results means that the possibility of home construction project activities can be completed on time is high enough.

Table 4. Comparison of house construction project time with CPM and PERT

Comparison	CPM	PERT	Difference
Time (Days)	131	136	5

Based on the table, it can be seen that the CPM method is more effective and efficient than PERT method. The total duration required for completion of a home construction project using the CPM method is 131 days, and by the PERT method is 136 days. This is because the CPM method has a definite duration estimation, whereas the PERT method has three estimation estimates.

5. Conclusion

Based on the result of the research, it can be concluded that:

1. The use of both methods in the scheduling of the house construction project is very significant effect on the project completion time (before 173 days).
2. The total duration required for a home construction project using the CPM method is 131 days, or save time up to 42 days.
3. The total duration required for a home construction project using the PERT method is 136 days. Based on PERT calculation, Z = - 0.66, The value of 0.2546 (from the normal distribution table), and the probability or probability of completing the project is 74.54 %. This means that the possibility of home construction project activities can be completed on time is high enough.

6. References

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