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Optimization of Flat Construction Implementation Time Using *Critical Path Method* and *Project Evaluation* and *Review Technique*

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ABSTRACT

This research aims to develop a system that effectively solves construction project management problems using PERT (Project Evaluation and Review Technique) and CPM (Critical Path Method) methods for the ASN flat construction project in Piru City, Maluku Province, Indonesia. In this study, the project activity data was analyzed using the PERT Method, which includes realistic, optimistic, and pessimistic durations; then, it is used to calculate the estimated time of each activity. Meanwhile, CPM was used to determine the critical path of the project. The results showed that project management can be done more accurately and efficiently with these two methods, minimizing the risk of delays. The optimal duration of the project obtained is 49 weeks with a probability value of 98.87% with the critical path obtained, namely A-B-E-F-G-J-K-L-M.

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1. Introduction

The essence of national development is the development of Indonesian people as a whole and all Indonesian people based on Pancasila and the Constitution [1]. In Indonesian society, housing as one of the basic human needs is the embodiment of the human self, both as a person and as a unity with others and the natural environment [2][3]. Many private and government parties are competing to carry out development, be it personal development or development for the welfare of the region. In addition to human development, national development is also in physical development [5].

In physical development, a term is known as a project, a temporary activity that has a limited time by seeking specific resources and can produce products or services whose quality criteria have been clearly defined. To develop the development task, project management is needed, which is one of the ways or processing methods developed scientifically and intensively since the mid-20th century to deal with special activities in the form of projects [6].

One type of physical development is a flat construction project. Flats were established as a government solution to providing livable housing for the lower middle class. A project schedule is needed to realize a project, which is determined by activities that are started, postponed, and completed. Project scheduling includes the sequence and division of time for all project activities. Therefore, managers decide how long each activity takes to complete and calculate how many people are needed for each production [7][8][9]

Some methods that can be used to analyze work network diagrams are CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) [10]. CPM is a design that can be utilized to develop project planning and scheduling. Through CPM, the duration of project completion and critical activities can be known [11] Meanwhile, PERT is a design used to predict the impact of time uncertainty in completing each project activity. The PERT method can also be used to evaluate or assess project activities to minimize the occurrence of disruptions or problems. This method is used to develop a project implementation schedule so that the activities of workers can be controlled and organized optimally [12].

Although PERT and CPM are similar in their basic approach, they differ in the estimated time required to perform the activity. For each activity, the PERT method uses three estimates (optimistic, realistic, and pessimistic time) to determine the expected completion time. Whereas, the CPM method uses a single estimate of activity time, assuming the activity time is known with certainty [13]. This study aims to apply the Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM) as a network diagram to map the flow and interrelationships between activities in the ASN flat construction project. Furthermore, this study seeks to analyze and determine the fastest completion time estimation, ensuring that the construction process can be carried out efficiently and according to the planned schedule.

2. Research method

This type of research method is quantitative. The method was carried out in the form of alternative planning of the optimal duration of the project with the CPM-PERT method based on data obtained from observations. The object of this research is flat, and the subject is project time control with the CPM-PERT method.

The implementation of this research is divided into several stages as follows:

a) Literature Study. Before starting the research, a literature study was conducted to deepen the knowledge of the topic to be studied by reading several books, lecture materials, journals, and references related to the research topic.

b) Data Collection. The project data required to support the research is collected at this stage. The data needed is the actual activity schedule of the flat project. The data was obtained from the contractor working on the project. The required data includes:
Primary data collection was carried out using the interview method. Interviews were conducted directly with several project experts consisting of questions containing the variables in this study, and each interviewee received the same questions from one another.
The primary data required are as follows:
   1. Project implementation activity list
   2. Linkages between activities
   3. Duration of project implementation

   Secondary data supporting data related to the construction of flat projects and some literature.

c) Determining the Research Object. To determine the research object, it is necessary to collect data and identify the problems to be studied. This study's intended object is the optimal duration of flat construction project implementation activities.

d) Research Implementation Primary and secondary data that were collected were then carried out research on alternative planning of the optimal duration of the project with the CPM-PERT Flat method with the following stages:

1. The implementation of the research began with determining the sequence of activities project in both the CPM and PERT methods and determining the duration for each activity stage.
2. The CPM method was continued by making *network planning* to find out the relationship between project activities.
3. The next step was forward and backward calculation to determine the *activity time*, which is the result of the *activity time* that can be used to calculate the Total *Float* (TF) value.
4. The calculated TF results show which work is affected by the critical path. Therefore, project time can be accelerated by summarizing the duration of activities on the critical path and obtaining the optimal project duration with the CPM method.
5. The PERT method can be continued by determining the best activity time for all activities on the critical path.
6. The variance of project activities on the critical path will later be used to determine the probability of project activities. Then, the standard distribution table Z is used to determine the probability of project completion time.
7. After obtaining the optimal duration from the two methods, compare the duration with the existing duration.

3. Results and Discussion

3.1. CPM

a. Arranging the Sequence of Activities

The activities are organized into a work network to find out the total time required for a flat construction project in Piru City. Before compiling a work network, it is necessary to sort each existing activity by the activity implementation order based on each activity's dependency logic [14][15]. The logic referred to in a work network is that an activity can be carried out if another activity that precedes it has been completed. In other words, the end of an activity is the beginning of the implementation of another activity. Then, there is a possibility that several activities can be carried out together without disrupting the implementation of each activity. Based on the logic of dependence mentioned above, the following table presents the sequence of activities for the construction of flat projects based on the interviews conducted by researchers with contractors for ASN (civil servant) flat construction projects in Piru City. Based on the interview, the construction of the flat project is presented in the table below.

Table 1. Sequence and duration of flat construction

Activities	Activities	Predecessor Activity	Duration (weeks)
Earthwork	A	-	3
Foundation & Concrete Work (1st floor)	B	A	9
Frame, Door, Window & Hanging Work (1st floor)	C	A	6
Wall & Plastering Work (1st floor)	D	B C	6
Concrete Work (2nd Floor)	E	B	7
Frame, Door, Window & Hanging Work (2nd floor)	F	E	6
Wall & Plastering Work (2nd floor)	G	D, F	5
Roof Work	H	E	4
Water Sanitation Works (1st, 2nd floor)	I	G	2
Electrical Installation Work (1st, 2nd floor)	J	G	3
Ceiling (1st, 2nd floor)	K	H, I, J	6
Ceramic Work (1st, 2nd floor)	L	K	4
Painting Work (1st, 2nd floor)	M	L	6

Data source: *(PT. Prima Konstruksi)*

From **Table 1**, it is known that the activities planned for the construction of ASN flats in Piru City are 13 activities symbolized by the letters A and followed by previous activities accompanied by the completion time of each activity sequence of activities that must be carried out before the implementation of the flat project. Activity B can only be done after activity A is completed. Activity K can only be done after activities H, I, and J have been completed. The same is true for the next activity.

b. Networking

Using the data from **Table 1**, a work network diagram chart can be prepared as follows:

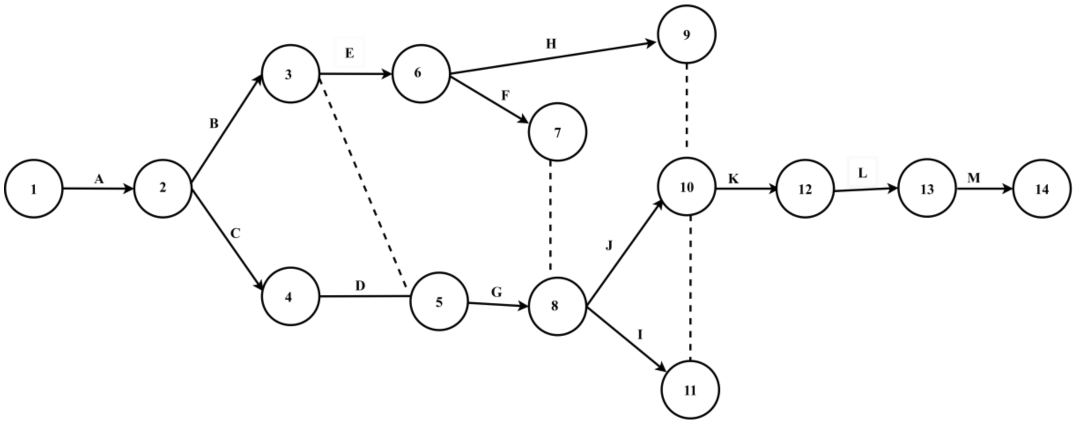

Figure 1. Network diagram of flat construction

From the work network diagram that has been made, do forward and backward calculations to determine slack or critical activities.

- **Forward calculation**

Given $E(1) = 0$ and $EF_{(i\text{–}j)} = ES_{(i\text{–}j)} + D_{(i\text{–}j)}$
Then,

$$EF_{(1-2)} = ES_{(1-2)} + D_{(1-2)} = 0+3 = 3$$
$$EF_{(2-3)} = ES_{(2-3)} + D_{(2-3)} = 3+9 = 12$$
$$EF_{(2-4)} = ES_{(2-4)} + D_{(2-4)} = 3+6 = 9$$
$$EF_{(3-5)} = ES_{(3-5)} + D_{(3-5)}$$
$$= \max\left(EF_{(2-3)}\,;\,EF_{(2-4)}\right)$$
$$= \max(12;9) + D_{(3-5)}$$
$$= 12+6 = 18$$
$$EF_{(4-6)} = ES_{(4-6)} + D_{(4-6)} = 12+7 = 19$$
$$EF_{(6-7)} = ES_{(6-7)} + D_{(6-7)} = 19+6 = 25$$
$$EF_{(5-8)} = ES_{(5-8)} + D_{(5-8)}$$
$$= \max\left(EF_{(3-5)}\,;\,EF_{(6-7)}\right)$$
$$= \max(18;25) + D_{(5-8)}$$
$$= 25+5 = 30$$
$$EF_{(6-9)} = ES_{(6-9)} + D_{(6-9)} = 19+4 = 23$$
$$EF_{(8-10)} = ES_{(8-10)} + D_{(8-10)} = 30+2 = 32$$
$$EF_{(8-11)} = ES_{(8-11)} + D_{(8-11)} = 30+3 = 33$$
$$EF_{(10-12)} = ES_{(10-12)} + D_{(10-12)}$$
$$= \max\left(EF_{(6-9)}\,;EF_{(8-10)}\,;\,EF_{(8-11)}\right)$$
$$= \max(23;32;\,33) + D_{(10-12)}$$
$$= 33+6 = 39$$
$$EF_{(12-13)} = ES_{(12-13)} + D_{(12-13)} = 39+4 = 43$$
$$EF_{(13-14)} = ES_{(13-14)} + D_{(13-14)} = 43+6 = 49$$

- **Backward Calculation**

Given $L(13) = 49$ and $LS_{(i\text{–}j)} = LF_{(i\text{–}j)} - te_{(i\text{–}j)}$
Then

$$LS_{(13-14)} = LF_{(13-14)} - D_{(13-14)} = 43-6 = 43$$
$$LS_{(12-13)} = LF_{(12-13)} - D_{(12-13)} = 43-4 = 39$$
$$LS_{(10-12)} = LF_{(10-12)} - D_{(10-12)} = 39-6 = 33$$
$$LS_{(8-11)} = LF_{(8-11)} - D_{(8-11)} = 33-3 = 30$$
$$LS_{(8-10)} = LF_{(8-10)} - D_{(8-10)} = 33-2 = 31$$

$$
\begin{aligned}
LS_{(6-9)} &= LF_{(6-9)} - D_{(6-9)} = 33 - 4 = 29 \\
LS_{(5-8)} &= LF_{(5-8)} - D_{(5-8)} \\
&= \min(LS_{(8-10)}\ ; LS_{(8-11)}) - D_{(5-8)} \\
&= \min(31; 30) - 5 = 25 \\
LS_{(6-7)} &= LF_{(6-7)} - D_{(6-7)} = 25 - 6 = 9 \\
LS_{(4-6)} &= LF_{(4-6)} - D_{(4-6)} = 19 - 7 = 12 \\
LS_{(3-5)} &= LF_{(3-5)} - D_{(3-5)} = 25 - 6 = 19 \\
LS_{(2-4)} &= LF_{(2-4)} - D_{(2-4)} = 19 - 6 = 13 \\
LS_{(2-3)} &= LF_{(2-3)} - D_{(2-3)} \\
&= \min\left(LS_{(3-5)}\ ; LS_{(4-6)}\right) - D_{(2-3)} \\
&= \min(19{,}6; 12) - D_{(2-3)} \\
&= 12 - 9 = 3 \\
LS_{(1-2)} &= LF_{(1-2)} - D_{(1-2)} \\
&= \min\left(LS_{(2-3)}\ ; LS_{(2-4)}\right) - D_{(1-2)} \\
&= \min(3; 13) - D_{(1-2)} \\
&= 3 - 3 = 0
\end{aligned}
$$

- **Determining Total Slack**

Slack Time or Total Slack $(TS) = LS - ES$ or $LF - EF$
The results of the calculation of forward, backward, and total *slack* can be poured into the following **Table 2**

Table 2. Total *slack* calculation results

Activities	Duration (weeks)	Earliest (week)		Latest (week)		Total Slack
		Start (ES)	End (EF)	Start (LS)	End (LF)	
A	3	0	3	0	3	0
B	9	3	12	3	12	0
C	6	3	9	13	19	10
D	6	12	18	19	25	7
E	7	12	19	12	19	0
F	6	19	25	19	25	0
G	5	25	30	25	30	0
H	4	19	23	29	33	10
I	2	30	32	31	33	1
J	3	30	33	30	33	0
K	6	33	39	33	39	0
L	4	39	43	39	43	0
M	6	43	49	43	49	0

Table 2. Critical activities with total *slack* = 0 are A - B - E - F - G - J - K - L - M with a period of 49 weeks. The results of forward and backward calculations can be poured into the form of a work network diagram as follows:

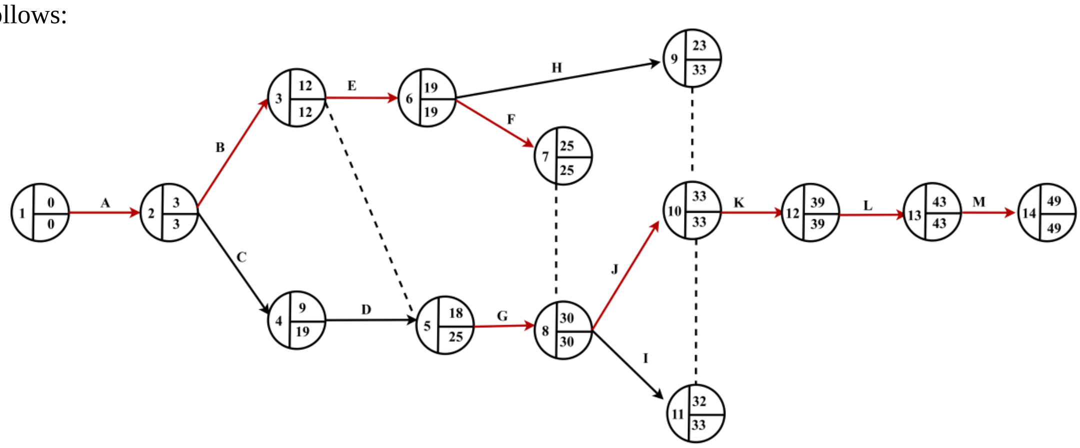

Figure 2. Forward and backward calculations for critical path determination

Figure 1 shows that there are 14 events (denoted by circles numbered 1- 14) that mark the start and end of an activity. There are 13 activities (symbolized by arrows coded A-M) that are part of the overall work and have time information. **Figure 2** is an explanatory picture of **Figure 1**. In **Figure 1**, a work network diagram is formed based on the data in **Table 1** and the rules of work network analysis. From the data in **Table 1**, the activities and predecessor activities are known. This means an existing activity can be carried out when the predecessor activity has been completed. In other words, there is a connection between these activities.

Forward and backward calculations are performed to obtain the EF and LS values used to calculate the value of total *slack*. From **Figure 2**, the forward calculation is done by summing up the ES value and the duration of the project activity work. Starting from *event* 1 to *event* 14. In *event* 1-2, it is known that the value of $ES = 0$ because no activity has been started, then summed with the duration of activity A, which is 3, then the value of $EF_{(1-2)}$ is obtained to be the new value for $ES_{(2-3)}$ so $EF_{(1-2)} = ES_{(2-3)}$. Furthermore, for *events* 2-4, it is known that the value of $EF_{(2-4)} = 3$ and then summed with the duration of activity C which is 6, the value of $EF_{(2-4)} = 3 + 6 = 9$. Furthermore, *events* 8-10 and 8-11 can be done when activity G or *events* 5-8 have been completed. The same applies to the following calculation.

Backward calculation is done by subtracting the LF value and activity duration. Starting from the back, namely from *event* 14 to *event* 1. In *the event* 14-13, it is known that the value of $LF = 49$ is subtracted from the duration of activity M, which is 6, to get $LS_{(14-13)} = 43$. Furthermore, the value of $LS_{(14-13)}$ becomes the new value for $LF_{(13-12)}$, so $LS_{(14-13)} = LF_{(13-12)}$. The same applies to the following calculation; it is just that it will be slightly different when there is more than one arrow pointing to the same *event*. For example, 2 arrows lead to *event* 8, namely *events* 8-11 and 8-10, so the most minor or minimum value is chosen. Based on the calculation results in **Table 2**, it is known that the value of $LS_{(8-10)} = 31$, while the value of $LS_{(8-11)} = 30$, the smallest value is chosen, namely 30. The value is used as the LF value in *event* number 8.

In **Figure 2**, there is a red arrow that indicates critical activity. Critical activity is an activity with a total *slack* or time allowance of zero (0). Activities with total *slack* = 0 mean that the activity must not have a time delay or be done according to the existing schedule. Because if there is a delay in work, it will delay the completion of the plan. Meanwhile, activities with total slack> 0 are the maximum time to be postponed to completing a job without delaying the overall planning work. Then, there is a dotted line that is a *dummy*, fictitious activity that does not require time or resources. *A dummy activity* shows the network diagram's dependency or logical relationship between other activities.

It is known that in **Figure 2**, the critical path formed from critical activities is A - B - E - F - G - J - K - L – M while non-critical activities are C - D - H -I. Non-critical activities are not activities that are not done, but the work can be done together with critical activities, and non-critical activities also have a grace period, which is the maximum time of delay. Therefore, the fastest time to complete the flat construction project in Piru City is 49 weeks.

3.2. PERT Method

a. Activity Sequencing

The PERT method uses three time estimates, namely optimistic time (a), pessimistic time (b), and realistic time (m), for each activity **[16][17]**. The following table estimates the activity time using the PERT method.

Table 3. Estimated Time in PERT Method

Activities	Predecessor Activities	a	m	b
A	-	2	3	4
B	A	8	9	10
C	A	4	6	8
D	B C	4	6	8
E	B	5	7	9
F	E	3	6	7
G	D,F	3	5	7
H	E	3	4	5
I	G	1	2	3
J	G	2	3	4
K	H,I,J	4	6	8
L	K	3	4	5
M	L	3	6	7

After making a time estimate, the value of te (expected time) is sought as follows.

$$te_A = \frac{2+4\times 3+4}{6} = \frac{18}{6} = 3$$
$$te_B = \frac{8+4\times 9+10}{6} = \frac{54}{6} = 9$$
$$te_C = \frac{4+4\times 6+8}{6} = \frac{36}{6} = 6$$
$$te_D = \frac{4+4\times 6+8}{6} = \frac{36}{6} = 6$$
$$te_E = \frac{5+4\times 7+9}{6} = \frac{42}{6} = 7$$
$$te_F = \frac{3+4\times 6+7}{6} = \frac{34}{6} = 5.6$$
$$te_G = \frac{3+4\times 5+7}{6} = \frac{30}{6} = 5$$
$$te_H = \frac{3+4\times 4+5}{6} = \frac{24}{6} = 4$$
$$te_I = \frac{1+4\times 2+3}{6} = \frac{12}{6} = 2$$
$$te_J = \frac{2+4\times 3+4}{6} = \frac{18}{6} = 3$$
$$te_K = \frac{4+4\times 6+8}{6} = \frac{36}{6} = 6$$
$$te_L = \frac{3+4\times 4+5}{6} = \frac{24}{6} = 4$$
$$te_M = \frac{2+4\times 6+7}{6} = \frac{33}{6} = 5{,}6$$

The te value of each activity is then presented in the form of **Table 4** below:

Table 4. Calculation of te

Activities	Predecessor Activity	a	m	b	te
A	-	2	3	4	3
B	A	8	9	10	9
C	A	4	6	8	6
D	B C	4	6	8	6
E	B	5	7	9	7
F	E	3	6	7	5,6
G	D,F	3	5	7	5
H	E	3	4	5	4
I	G	1	2	3	2
J	G	2	3	4	3
K	H,I,J	4	6	8	6
L	K	3	4	5	4
M	L	3	6	7	5,6

b. Determination of Critical Activities and Critical Path

- **Forward Calculation**

Given $E(1) = 0$ and $EF_{(i-j)} = ES_{(i-j)} + te_{(i-j)}$
Then

$$EF_{(1-2)} = ES_{(1-2)} + te_{(1-2)} = 0 + 3 = 3$$
$$EF_{(2-3)} = ES_{(2-3)} + te_{(2-3)} = 3 + 9 = 12$$
$$EF_{(2-4)} = ES_{(2-4)} + te_{(2-4)} = 3 + 6 = 9$$
$$EF_{(3-5)} = ES_{(3-5)} + te_{(3-5)}$$
$$= \max\left(EF_{(2-3)}\,;\, EF_{(2-4)}\right)$$
$$= \max\,(12; 9) = 12 + 6 = 18$$
$$EF_{(4-6)} = ES_{(4-6)} + te_{(4-6)} = 12 + 7 = 19$$
$$EF_{(6-7)} = ES_{(6-7)} + te_{(6-7)} = 19 + 5{,}6 = 24{,}6$$
$$EF_{(5-8)} = ES_{(5-8)} + te_{(5-8)}$$
$$= \max\left(EF_{(3-5)}\,;\, EF_{(4-6)}\right)$$

$$= \max(18; 24{,}6) = 24{,}6 + 5 = 29{,}6$$

$$EF_{(6-9)} = ES_{(6-9)} + te_{(6-9)} = 19 + 4 = 23$$

$$EF_{(8-10)} = ES_{(8-10)} + te_{(8-10)} = 29{,}6 + 2 = 31{,}6$$

$$EF_{(8-11)} = ES_{(8-11)} + te_{(8-11)} = 29{,}6 + 3 = 32{,}6$$

$$EF_{(10-12)} = ES_{(10-12)} + te_{(10-12)}$$

$$= \max\left(EF_{(6-9)}; EF_{(8-10)}; EF_{(8-11)}\right)$$

$$= \max(23; 31{,}6; 32{,}6) = 33 + 6 = 39$$

$$EF_{(12-13)} = ES_{(12-13)} + te_{(12-13)} = 38{,}6 + 4 = 42{,}6$$

$$EF_{(13-14)} = ES_{(13-14)} + te_{(13-14)} = 42{,}6 + 6 = 48{,}3$$

- **Backward Calculation**

Given $L(13) = 48{,}3$ and $EF_{(i-j)} = ES_{(i-j)} + te_{(i-j)}$

Then

$$LS_{(13-14)} = LF_{(13-14)} - te_{(13-14)} = 48{,}3 - 5{,}6 = 42{,}6$$

$$LS_{(12-13)} = LF_{(12-13)} - te_{(12-13)} = 42{,}6 - 4 = 38{,}6$$

$$LS_{(10-12)} = LF_{(10-12)} - te_{(10-12)} = 38{,}6 - 6 = 32{,}6$$

$$LS_{(8-11)} = LF_{(8-11)} - te_{(8-11)} = 32{,}6 - 3 = 29.6$$

$$LS_{(8-10)} = LF_{(8-10)} - te_{(8-10)} = 32{,}6 - 2 = 30.6$$

$$LS_{(6-9)} = LF_{(6-9)} - te_{(6-9)} = 32{,}6 - 4 = 28{,}6$$

$$LS_{(5-8)} = LF_{(5-8)} - te_{(5-8)}$$

$$= \min\left(LS_{(8-10)}; LS_{(8-11)}\right)$$

$$= \min(30{,}6; 29{,}6) = 29{,}6 - 5 = 24{,}6$$

$$LS_{(6-7)} = LF_{(6-7)} - te_{(6-7)} = 24{,}6 - 5{,}6 = 19$$

$$LS_{(4-6)} = LF_{(4-6)} - te_{(4-6)}$$

$$= \min\left(LS_{(6-7)}; LS_{(6-9)}\right) - te_{(4-6)}$$

$$= \min(19; 28{,}6) - te_{(4-6)}$$

$$= 19 - 7 = 12$$

$$LS_{(3-5)} = LF_{(3-5)} - te_{(3-5)} = 24{,}6 - 6 = 18{,}6$$

$$LS_{(2-4)} = LF_{(2-4)} - te_{(2-4)} = 18{,}6 - 6 = 12{,}6$$

$$LS_{(2-3)} = LF_{(2-3)} - te_{(2-3)}$$

$$= \min\left(LS_{(3-5)}; LS_{(4-6)}\right) - te_{(2-3)}$$

$$= \min(18{,}6; 12) - te_{(2-3)}$$

$$= 12 - 9 = 3$$

$$LS_{(1-2)} = LF_{(1-2)} - te_{(1-2)}$$

$$= \min\left(LS_{(2-3)}; LS_{(2-4)}\right) - te_{(1-2)}$$

$$= \min(3; 12{,}6) - te_{(1-2)}$$

$$= 3 - 3 = 0$$

- **Variance**

Using pessimistic and optimistic time estimates, the variance of each activity can be calculated.

$$Variance\ (A) = \left(\frac{4-2}{6}\right)^2 = 0{,}11$$

$$Variance\ (B) = \left(\frac{10-8}{6}\right)^2 = 0{,}11$$

$$Variance\ (C) = \left(\frac{8-4}{6}\right)^2 = 0{,}44$$

$$Variance\ (D) = \left(\frac{8-4}{6}\right)^2 = 0{,}44$$

$$Variance\ (E) = \left(\frac{9-5}{6}\right)^2 = 0{,}44$$

$$Variance\ (F) = \left(\frac{7-3}{6}\right)^2 = 0{,}44$$

$$Variance\ (G) = \left(\frac{7-3}{6}\right)^2 = 0{,}44$$

$$Variance\ (H) = \left(\frac{5-3}{6}\right)^2 = 0{,}44$$
$$Variance\ (I) = \left(\frac{3-1}{6}\right)^2 = 0{,}11$$
$$Variance\ (J) = \left(\frac{4-2}{6}\right)^2 = 0{,}11$$
$$Variance\ (K) = \left(\frac{8-4}{6}\right)^2 = 0{,}44$$
$$Variance\ (L) = \left(\frac{5-3}{6}\right)^2 = 0{,}11$$
$$Variance\ (M) = \left(\frac{7-3}{6}\right)^2 = 0{,}44$$

The results of forward, backward, and variance calculations are presented in **Table 5** below:

Table 5. Total *slack* and variance calculation results

Activities	ES	EF	LS	LF	Slack	Variance
A	0	3	0	3	0	0,11
B	3	12	3	12	0	0,11
C	3	9	12,6	18,6	9,6	0,44
D	12	18	18,6	24,6	6,6	0,44
E	12	19	12	19	0	0,44
F	19	24,6	19	24,6	0	0,44
G	24,6	29,6	24,6	29,6	0	0,44
H	19	23	28,6	23,6	9,6	0,44
I	29,6	31,6	30,6	32,6	1	0,11
J	29,6	32,6	29,6	32,6	0	0,11
K	32,6	38,6	32,6	38,6	0	0,44
L	38,6	42,6	38,6	42,6	0	0,11
M	42,6	48,3	42,6	48,3	0	0,44

- **Probability**

The variance value of critical activities is required to calculate the expected time probability. The following is the total variance value of critical activities.

$$\sum Variance_{Critical} = 0{,}11 + 0{,}11 + 0{,}44 + 0{,}44 + 0{,}44 + 0{,}11 + 0{,}44 + 0{,}11 + 0{,}44$$
$$= 2{,}46 = \sqrt{2{,}46} = 1{,}62$$

Then, the z-normal value will be found, with the desired project delivery target of 52 weeks.

$$z - normal = \frac{52-49}{1{,}62} = \frac{3}{1{,}62} = 1{,}85$$

The probability that the project will be completed within 52 weeks is 96%.

3.3. Use of POM-QM Software

To improve the accuracy and efficiency of project management analysis using POM-QM for Windows version 5.2 software. POM-QM is widely known for its ability to handle complex project scheduling and optimization problems through techniques such as the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT).

The result of CPM Method

QM for Windows - [Data] Results

METODE CPM Solution

Activity	Activity time	Early Start	Early Finish	Late Start	Late Finish	Slack
Project	49					
A	3	0	3	0	3	0
B	9	3	12	3	12	0
C	6	3	9	13	19	10
D	6	12	18	19	25	7
E	7	12	19	12	19	0
F	6	19	25	19	25	0
G	5	25	30	25	30	0
H	4	19	23	29	33	10
I	2	30	32	31	33	1
J	3	30	33	30	33	0
K	6	33	39	33	39	0
L	4	39	43	39	43	0
M	6	43	49	43	49	0

Figure 3. **CPM Calculation Results using POM-QM**

The results of the CPM analysis show that the critical activities of the ASN flat construction project in Piru City are A - B - E - F - G - J - K - L - M which identifies activities that have no *slack* and therefore must be completed on time to avoid delaying the entire project.

The result of PERT Method

QM for Windows - [Data] Results

METODE PERT Solution

Activity	Activity time	Early Start	Early Finish	Late Start	Late Finish	Slack	Standard Deviation	Variance
Project	48,33						1,63	2,67
A	3	0	3	0	3	0	,33	,11
B	9	3	12	3	12	0	,33	,11
C	6	3	9	12,67	18,67	9,67	,67	,44
D	6	12	18	18,67	24,67	6,67	,67	,44
E	7	12	19	12	19	0	,67	,44
F	5,67	19	24,67	19	24,67	0	,67	,44
G	5	24,67	29,67	24,67	29,67	0	,67	,44
H	4	19	23	28,67	32,67	9,67	,33	,11
I	2	29,67	31,67	30,67	32,67	1	,33	,11
J	3	29,67	32,67	29,67	32,67	0	,33	,11
K	6	32,67	38,67	32,67	38,67	0	,67	,44
L	4	38,67	42,67	38,67	42,67	0	,33	,11
M	5,67	42,67	48,33	42,67	48,33	0	,67	,44

Figure 4. **PERT calculation results using POM-QM**

Through PERT analysis, the expected time (te) for project completion of 48.3 weeks was calculated by considering the uncertainty in the activity duration. Variations are calculated to measure the risk of delay and the probability of completing the project within a specific time.

3.4. Result Representation

Based on the results of the analysis using the work diagram, the fastest completion time for the flat construction project is 49 weeks. The known critical path is A - B - E - F - G - J - K - L - M or Earthwork - Foundation & Concrete Work (Floor 1) - Concrete Work (Floor 2) - Frame, Door, Window & Hanging Work (Floor 2) - Wall & Plastering Work (Floor 2) - Electrical Installation Work (Floor 1, 2) - Ceiling Work (Floor 2) - Ceramic Work (Floor 1, 2). - Painting Work (1st, 2nd Floor). By considering the critical path and the time obtained, several implications can be drawn for future projects, including improved project time planning and proper allocation of resources according to the specified timeline. It can be seen that this project has a set duration of 52 weeks, but based on optimal time analysis, the project can be completed in 49 weeks

4. Conclusion

Based on data analysis of the research results in the case of the ASN flat construction project in Piru City, the researchers draw the following conclusions: In the research, it can be found that the critical path of the flat construction project is A - B - E - F - G - J - K - L - M or Earthwork - Foundation & Concrete Work (1st Floor) - Concrete Work (2nd Floor) - Frame, Door, Window & Hanging Work (2nd Floor) - Wall & Plastering Work (2nd Floor) - Electrical Installation Work (1st, 2nd Floor) - Ceiling Work (2nd Floor) - Ceramic Work (1st, 2nd Floor). - Painting Work (1st, 2nd Floor) and based on the work network diagram analysis, the fastest completion time for the Piru City ASN flat construction project is 49 weeks.

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