



IMPLEMENTATION OF PROJECT MANAGEMENT SCHEDULING USING CRITICAL PATH METHOD (CPM) AND PROJECT EVALUATION AND REVIEW TECHNIQUE (PERT) IN THE HOUSE CONSTRUCTION PROJECT IN THE MALIMBUKAN PERMAI III HOUSING AREAS IN NORTH MINAHASA REGENCY

IMPLEMENTASI PENJADWALAN MANAJEMEN PROYEK MENGGUNAKAN METODE JALUR KRITIS (CPM) DAN TEKNIK EVALUASI DAN KAJIAN PROYEK (PERT) PADA PROYEK PEMBANGUNAN RUMAH DI PERUMAHAN MALIMBUKAN PERMAI III KABUPATEN MINAHASA UTARA

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Abstract

Previous studies have shown that the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT) are effective in optimizing project completion time. Based on observations, the construction of a single housing unit typically requires 64 working days. This study aims to obtain an optimal scheduling result by applying CPM and PERT to the construction project of a subsidized house type-36 in Perumahan Malimbukan Permai III, North Minahasa Regency. The analysis results indicate that the project's critical path consists of A – B – C – D – E – F – H – K – L – M – N – P – Q. Using the CPM method, the required completion time is 55 days, while the PERT method yields an estimated 55.68 days. With a deadline of 60 days, the probability of completing the project is 99.94%. This study highlights the importance of monitoring the critical path and utilizing time estimation in project planning to prevent delays and unforeseen obstacles.

Keywords : Project Management, CPM, PERT.

Abstrak

Penelitian-penelitian terdahulu menunjukkan bahwa metode Critical Path Method (CPM) dan Project Evaluation and Review Technique (PERT) mampu mengoptimalkan waktu penyelesaian suatu proyek. Berdasarkan observasi, pembangunan satu unit rumah membutuhkan waktu 64 hari kerja. Penelitian ini



bertujuan untuk memperoleh hasil penjadwalan yang optimal dengan menggunakan CPM dan PERT pada proyek pembangunan rumah subsidi tipe 36 di Perumahan Malimbukan Permai III, Kabupaten Minahasa Utara. Hasil analisis menunjukkan bahwa jalur kritis proyek adalah A – B – C – D – E – F – H – K – L – M – N – P – Q. Berdasarkan metode CPM, waktu penyelesaian yang dibutuhkan adalah 55 hari, sedangkan metode PERT menghasilkan estimasi 55,68 hari. Dengan tenggat waktu 60 hari, probabilitas penyelesaian proyek mencapai 99,94%. Studi ini menekankan pentingnya pengawasan jalur kritis serta penggunaan estimasi waktu dalam perencanaan proyek guna mencegah keterlambatan dan kendala tak terduga.

Kata Kunci : Manajemen Proyek, CPM, PERT.

1. INTRODUCTION

As a developing country located in Southeast Asia, Indonesia must catch up with its neighbors. As Indonesia approaches its golden age of 2045, much remains to be done. One effort is to promote infrastructure development. According to the International Institute for Management Development (IMD) World Competitive Ranking, Indonesia is ranked 27th in 2024, making it the country with the highest competitiveness, ranking among the top three in Southeast Asia. This is due to the fact that since 2019, infrastructure development has become one of the country's top priorities. (Secretariat of the Directorate General of Construction Development, 2024).

In line with the President's vision to build 3 million homes for low-income communities, the government's role in building basic infrastructure, including housing, is limited to facilitating access to adequate housing by providing subsidies, conducting research and development, and developing regulations for housing development. Subsidized housing projects are carried out by private developers in collaboration with the government through the Public-Private Partnership (PPP) scheme. Private developers significantly contribute to the development of housing projects. One example is PT. Dua Mutiara Sejati, with its Malimbukan Permai III project, which sells subsidized housing.

Based on observations and interviews with developers, a common occurrence is that buildings are not yet ready for occupancy during the contract period due to electricity not being turned on, water pipes not being connected, houses not being painted, zinc not being installed, and other issues. This can occur due to constraints caused by external factors such as unpredictable weather, logistical disruptions, and the aftermath of the COVID-19 pandemic, as well as internal factors such as labor shortages, equipment shortages, and inadequate project management, resulting in projects not being completed within the allotted deadlines. In 2023, five houses were built, four of which were delayed. In 2024, seven houses were built, six of which were delayed. From January 2025 to March 2025, four houses were built, three of which were delayed.

Research conducted by Noer Karina Tika Saputri (2022) showed positive results in the Andara housing development in Tarakan City, where project scheduling significantly contributes to project success. A structured project schedule helps optimize project activities by taking into account resources such as labor, materials, equipment allocation, critical path



allocation, budget, and probability, allowing for an estimate of the likelihood of project completion within the planned deadline.

Project scheduling can outline each interrelated and interdependent task within a construction project. Project scheduling techniques are complex and carry significant risks, including cost overruns and project delays. All consequences of scheduling and project control are the responsibility of the project manager. Based on this, researchers are interested in conducting research on this topic.

The application of project scheduling management in the Malimbukan Permai III housing development project will be carried out using the Critical Path Method (CPM) approach, namely by creating a network and then identifying the critical path which is the most important part of the project so that the duration of the work will be more optimal and the Project Evaluation and Review Technique (PERT) approach, namely a tool for planning, scheduling, and controlling complex projects by using three time estimates for each activity consisting of optimistic time (fastest), most likely time, and pessimistic time (longest). These two methods have been commonly used in a project. However, in the housing development project at Malimbukan Permai III Housing, these scheduling methods have not been used. The researcher intends to re-analyze existing housing development projects by implementing the CPM method and the PERT method on completed housing projects..

2. RESEARCH METHOD

This research uses a quantitative method. Quantitative methods can be defined as a philosophy of positivism that views reality as classifiable, relatively stable, concrete, measurable, observable, and causally related. The research process is conducted using a deductive approach, answering the problem formulation using concepts or theories to form hypotheses (Sugiyono, 2023:16). This research will present data in the form of numerical depictions of the time duration for each activity in the Malimbukan Permai III housing development project.

Data analysis using network methods is an important technique in project management used for planning, scheduling, and controlling complex projects with many interdependent activities. Two commonly used network methods are the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT). These techniques have similar basic concepts but differ in their time estimation approaches. CPM uses a single optimal time estimate for each activity, while PERT uses a probabilistic approach with three time estimates: optimistic, realistic, and pessimistic. The network is depicted using nodes to indicate events, arrows for activities, and dashed lines for dummy activities, with the stipulation that each activity has one direction of flow, one code, and moves from low to high numbered events, and has only one starting point.



3. RESULT AND DISCUSSION

a. CPM Activity Duration

Time estimation for the Malimbukan Permai III housing complex using the CPM method uses a single time estimate. Each activity has a code, a preceding activity, and a duration, which indicates how long each activity will take to complete. The following data is used to use the CPM method:

Tabel 1. CPM Activity Duration

List	Activity	Newest Activity	Duration
A	Persiapan	-	2
B	Pondasi	A	3
C	Sloof	B	3
D	Tiang Kolom	C	6
E	Penyusunan Batako dan Pemasangan Kusen	D	8
F	Ring Balk	E	5
G	Instalasi Listrik	E	1
H	Sopi-Sopi	F	3
I	Rangka Atap	H, G	2
J	Pemasangan Atap	I	2
K	Plesteran	H, G	6
L	Melamir/Acian	K	5
M	Plafon	J, L	3
N	Keramik	M	5
O	Pengerjaan WC	M	4
P	Cat	N	3
Q	Finishing	O,P	3

b. Network Diagram and Critical Path Determination Using CPM

Based on the data obtained from the table above, the network formed using the Activity On Node (AON) method is as presented in Figure 1 below.

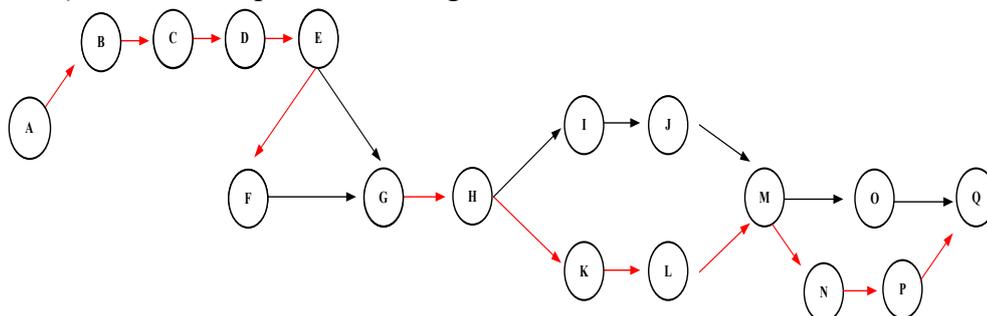


Figure 1. Activity On Node (AON) Network

In the network above, 17 nodes are produced with red arrows indicating critical path activities which can be identified through calculations from the Activity On Arrow (AOA) network image, as in Figure 2 below.

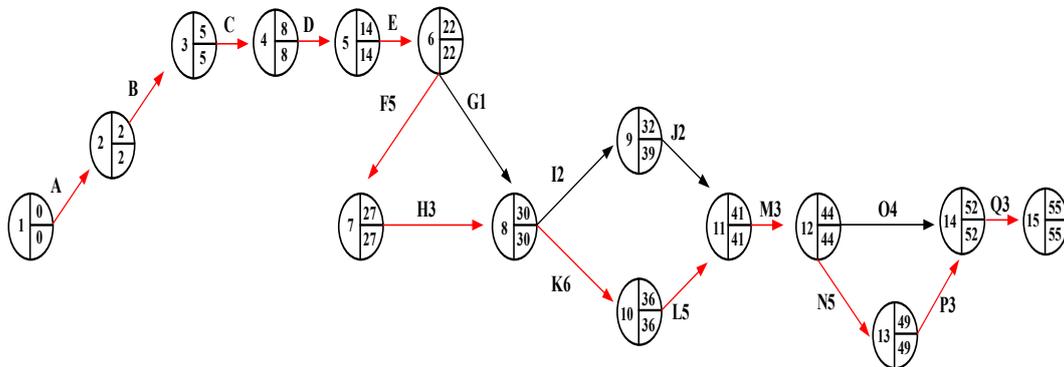


Figure 2. Activity On Node (AON) Network

The network diagram above shows a network diagram using the Activity On Arrow (AOA) method, resulting in 15 nodes and 17 arrows. The red arrows represent critical path activities. The numbers in the circles are explained in Figure 3.1. The eight networks formed are as follows:

- 1) A – B – C – D – E – F – H – K – L – M – O – Q = 51 Days
- 2) A – B – C – D – E – F – H – K – L – M – N – P – Q = 55 Days
- 2) A – B – C – D – E – F – H – I – J – M – O – Q = 44 Days
- 3) A – B – C – D – E – F – H – I – J – M – N – P – Q = 37 Days
- 4) A – B – C – D – E – G – I – J – M – O – Q = 37 Days
- 5) A – B – C – D – E – G – I – J – M – N – P – Q = 41 Days
- 6) A – B – C – D – E – G – K – L – M – O – Q = 44 Days
- 7) A – B – C – D – E – G – K – L – M – N – P – Q = 48 Days

The critical path is the longest sequence of project activities that determines the overall project completion time. The critical path is a series of activities that cannot be delayed, as a delay in any one activity will result in a delay to the entire project. In the sequence of paths formed above, the critical path is A – B – C – D – E – F – H – K – L – M – N – P – Q, which is 55 days, meaning it is 9 days faster than the actual work of 64 days.

c. Activity Time Estimation in PERT Method

The PERT method uses three time estimates: optimistic (fastest), realistic (normal), and pessimistic (longest). The following table shows activity time estimates using the PERT method:

Table 2. Activity Time Duration Using PERT Method

Order	Optimistic Time	Realistic Time	Pessimistic Time
A	1	2	3
B	3	3	4
C	3	3	4
D	5	6	7
E	6	8	10
F	3	5	5
G	1	1	2



Order	Optimistic Time	Realistic Time	Pessimistic Time
H	3	3	4
I	2	2	2
J	2	2	4
K	6	6	7
L	5	5	8
M	2	3	4
N	4	5	5
O	4	4	6
P	3	3	4
Q	2	3	3

d. Network and Determining the Critical Path with PERT

To find out the critical path using the PERT method, you must first calculate T_E (the estimated expected activity time) using the following formula:

$$T_E = \frac{T_0 + 4T_m + T_p}{6}$$

Table 3. E Calculation

Order	Calculation	T E
A	$\frac{1 + (4.2) + 3}{6}$	2
B	$\frac{3 + (4.3) + 4}{6}$	3.17
C	$\frac{3 + (4.3) + 4}{6}$	3.17
D	$\frac{5 + (4.6) + 7}{6}$	6
E	$\frac{6 + (4.8) + 10}{6}$	8
F	$\frac{3 + (4.5) + 5}{6}$	4.67
G	$\frac{1 + (4.1) + 2}{6}$	1.17
H	$\frac{3 + (4.3) + 4}{6}$	3.17
I	$\frac{2 + (4.2) + 2}{6}$	2
J	$\frac{2 + (4.2) + 4}{6}$	2.33
K	$\frac{6 + (4.6) + 7}{6}$	6.17
L	$\frac{5 + (4.5) + 8}{6}$	5.5



Order	Calculation	T E
M	$\frac{2 + (4.3) + 4}{6}$	3
N	$\frac{4 + (4.5) + 5}{6}$	4.83
O	$\frac{4 + (4.4) + 6}{6}$	4.33
P	$\frac{3 + (4.3) + 4}{6}$	3.17
Q	$\frac{2 + (4.3) + 3}{6}$	2.83

Based on table 3 which produces the expected time (TE), the next step is to determine the *Early Finish* (EF), to get the EF result for building a house in the Malimbukan Permai III Housing Complex, type 36 house, namely by adding TE with ES, namely as follows.

Table 4. Early Start and Early Finish

Order	T E	ICE	EF
A	2	0	2
B	3.17	2	5.17
C	3.17	5.17	8.33
D	6	8.33	14.33
E	8	14.33	22.33
F	4.67	22.33	27
G	1.17	22.33	23.5
H	3.17	27	30.17
I	2	30.17	32.17
J	2.33	32.17	34.5
K	6.17	30.17	36.33
L	5.5	36.33	41.83
M	3	41.83	44.83
N	4.83	44.83	49.67
O	4.33	44.83	49.17
P	3.17	49.67	52.83
Q	2.83	52.83	55.67

Early start is the earliest possible time an activity can begin. Early finish is the earliest possible time a project can be completed if there are no obstacles. For example, the final activity, whose QEF is 55.67, means that the activity cannot be completed before 55.67 days.

The next step is to determine the *Late Start* (LS). To calculate LS, use the TE – LF formula, as presented in Table 4.5 below:

Table 5. Late Finish and Late Start

Order	T E	LF	LS
A	2	2	0



Order	TE	LF	LS
B	3.17	5.17	2
C	3.17	8.33	5.17
D	6	14.33	8.33
E	8	22.33	14.33
F	4.67	27	22.33
G	1.17	30.17	29
H	3.17	30.17	27
I	2	39.5	37.5
J	2.33	41.83	39.5
K	6.17	36.33	30.17
L	5.5	41.83	36.33
M	3	44.83	41.83
N	4.83	49.67	44.83
O	4.33	52.83	48.5
P	3.17	52.83	49.67
Q	2.83	55.67	52.83

Late Start is the latest time an activity can begin. If an activity starts later than the LS, the project will experience a complete delay. Late Finish is the latest time an activity can be completed to avoid project delays. After determining ES, EF, LS, and LF, the next step is to calculate the amount of *slack* using the formula $LS - ES$ or $EF - LF$. The results are presented in Table 6 below:

Table 6. Slack

Order	TE	ICE	EF	LF	LS	Slack
A	2	0	2	2	0	0
B	3.17	2	5.17	5.17	2	0
C	3.17	5.17	8.33	8.33	5.17	0
D	6	8.33	14.33	14.33	8.33	0
E	8	14.33	22.33	22.33	14.33	0
F	4.67	22.33	27	27	22.33	0
G	1.17	22.33	23.5	30.17	29	6.67
H	3.17	27	30.17	30.17	27	0
I	2	30.17	32.17	39.5	37.5	7.33
J	2.33	32.17	34.5	41.83	39.5	7.33
K	6.17	30.17	36.33	36.33	30.17	0
L	5.5	36.33	41.83	41.83	36.33	0
M	3	41.83	44.83	44.83	41.83	0
N	4.83	44.83	49.67	49.67	44.83	0
O	4.33	44.83	49.17	52.83	48.5	3.67



Order	TE	ICE	EF	LF	LS	Slack
P	3.17	49.67	52.83	52.83	49.67	0
Q	2.83	52.83	55.67	55.67	52.83	0

Slack/Float is a grace period or flexible time which means that activities with slack >0 (more than zero) can be postponed to start according to the amount of slack without affecting all project activities. Activities with *slack* 0 (zero) are activities that go through the critical path, meaning they should not be delayed or late because it will affect the overall project time. While activities that have *slack* more than 0 are not critical paths, namely activity G with slack 6.67 means it can be delayed for 6.67 days., I with slack 7.33 means the activity can be delayed for 7.33 days., J has slack of 7.33 means this activity can be delayed for 7.33 days., and activity O with slack 3.67 means that activity O can be delayed up to 3.67 days and will not affect the overall project time. the results formed from the calculations above create 8 different paths as follows:

1. A – B – C – D – E – F – H – K – L – M – O – Q = 53.18 Days
2. A – B – C – D – E – F – H – K – L – M – N – P – Q = 55,68 Hari
3. A – B – C – D – E – F – H – I – J – M – O – Q = 45,84 Hari
4. A – B – C – D – E – F – H – I – J – M – N – P – Q = 49,51 Hari
5. A – B – C – D – E – G – I – J – M – O – Q = 42,67 Hari
6. A – B – C – D – E – G – I – J – M – N – P – Q = 46,34 Hari
7. A – B – C – D – E – G – K – L – M – O – Q = 50,01 Hari
8. A – B – C – D – E – G – K – L – M – N – P – Q = 53,68 Hari

Based on the results of the analysis of the existing PERT path calculations, the critical path or the longest path taken was found, namely with a duration of 55.68 days or 56 days of optimal work on the project to build collateral for one housing unit in the Malimbukan Permai III Housing Complex.

e. Calculating Probability

To calculate the probability using the formula:

$$z = \frac{T(d) - TE}{\sigma}$$

So first it is necessary to calculate the standard deviation and variance using the formula:

$$\text{Standar Deviasi (S)} = \frac{b - a}{6}$$

$$\text{Varians } (\sigma) = S^2$$

Table 7. Standard Deviation and Variance

Order	Optimistic Time	Realistic Time	Pessimistic Time	Standard Deviation	Variance
A	1	2	3	0.33	0.11
B	3	3	4	0.17	0.03
C	3	3	4	0.17	0.03
D	5	6	7	0.33	0.11



Order	Optimistic Time	Realistic Time	Pessimistic Time	Standard Deviation	Variance
E	6	8	10	0.67	0.44
F	3	5	5	0.33	0.11
G	1	1	2	0.17	0.03
H	3	3	4	0.17	0.03
I	2	2	2	0	0
J	2	2	4	0.33	0.11
K	6	6	7	0.17	0.03
L	5	5	8	0.5	0.25
M	2	3	4	0.33	0.11
N	4	5	5	0.17	0.03
O	4	4	6	0.33	0.11
P	3	3	4	0.17	0.03
Q	2	3	3	0.17	0.03
Total	55	64	82	4.51	1.59
Total Critical Path				3.68	1.34

Standard deviation measures the average deviation from expectations in the same standard unit. Variance measures the degree of data spread, or how much processing time can vary. This means that if the variance is small, the data is quite stable and certain. Although the variance formula is S^2 But the variance is not always greater than the standard deviation. In this case, the variance is <1 (less than one), so the standard deviation appears larger.

After obtaining the standard deviation and variance values, you can then determine the probability by entering the numbers obtained into the formula as below:

$$z = \frac{60 - 55,68}{1,34} = 3,22$$

Referring to the Z distribution table in Appendix 1, a Z value of 3.22 is found to the right of the mean value, which identifies a probability of 0.9994, meaning there is a 99.94% chance that this project can be completed within a maximum of 60 days. The following is a table of the probability that this project will be completed within a maximum of 60 days or less:

Table 8. Probability

No.	Target Completion Time	Z Deviation	Cumulative Normal Distribution	Probability
1	60	3.223880597	0.9994	99.94%
2	59	2.47761194	0.9932	99.32%
3	58	1.731343284	0,9582	95,82%



4	57	0.985074627	0,8365	83,65%
5	56	0.23880597	0,5910	59,10%

The table above explains that in the target time column is the expected time or expected time, in the Z deviation column is the uncertainty of the duration, for example, in a 60-day deadline with a Z standard deviation of 3.22, the project could run 3.22 days faster or 3.22 days slower. Next, in the cumulative normal distribution column is the Z value that is matched between the Z deviation value and the normal distribution Z table in appendix 1. Then in the probability column is the chance that the project can be completed within that time period.

f. Network Analysis

The network formed contains 17 nodes in the AON method as shown in Figure 3 and 15 nodes with the AOA method as shown in Figure 4. The following is an image of the AON network with the CPM and PERT methods using POM QM For Windows Ver. 5.3.

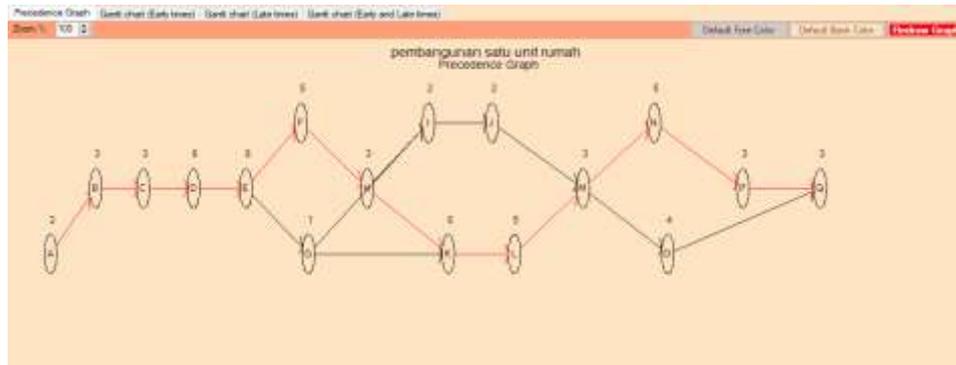


Figure 4. CPM Network Using POM QM For Windows Ver. 5.3

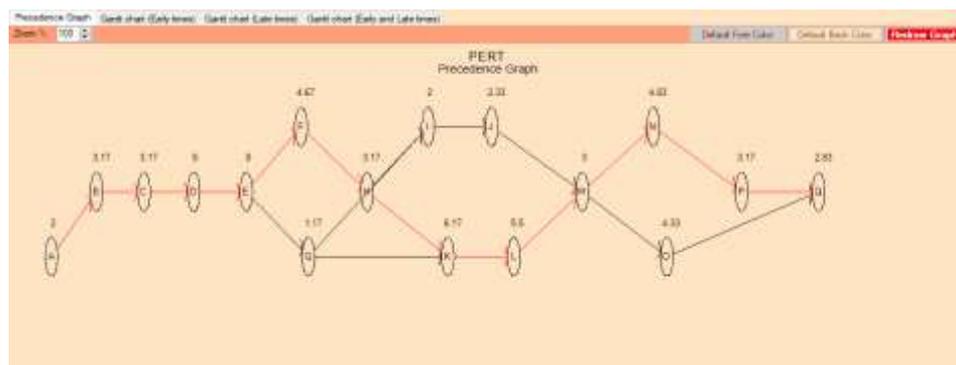


Figure 5. PERT Network Using POM QM For Windows Ver. 5.3

g. Analysis of Optimal Time Calculation and Probability Using CPM and PERT Methods

The results of this manual calculation produce the same results as the calculations using the POM QM For Windows Ver. 5.3 application, which presents the results of data processing using the CPM and PERT methods as follows:



- 1) The optimal time calculation using the CPM method yielded 55 days, which is 9 days shorter than the actual scheduled completion time using the traditional method. The calculation using the PERT method yielded 55.68 working days, or 56 days, which is 8 days shorter than the actual scheduled completion time using the traditional method. There is a 99% probability that this project can be completed within a maximum of 60 days.

Activity	Optimal time	Most Likely time	Pessimistic time	Activity time	Standard Deviation	Variance
A	1	2	3	2	33	11
B	3	3	4	3.17	17	05
C	3	3	4	3.17	17	05
D	5	6	7	6	36	11
E	6	6	10	8	67	44
F	3	3	6	4.67	33	11
G	1	1	2	1.17	17	05
H	3	3	4	3.17	17	05
I	2	2	2	2	0	0
J	2	2	4	2.67	33	11
K	6	6	7	6.17	17	05
L	5	5	6	5.5	5	25
M	2	3	4	3	33	11
N	4	5	5	4.67	17	05
O	4	4	6	4.33	33	11
P	3	3	4	3.17	17	05
Q	2	3	3	2.67	17	05
Project results						
Date of CR critical path						1.33

Figure 6. CPM Calculation Results Using POM QM For Windows Ver. 3.5

Activity	Activity time	Early Start	Early Finish	Late Start	Late Finish	Slack	Standard Deviation	Variance
A	2	0	2	0	2	0	1.15	1.33
B	3.17	2	5.17	2	5.17	0	17	05
C	3.17	5.17	8.34	5.17	8.34	0	17	05
D	6	6.33	14.33	6.33	14.33	0	36	11
E	8	14.33	22.33	14.33	22.33	0	67	44
F	4.67	22.33	27	22.33	27	0	33	11
G	1.17	22.33	23.5	26	26.17	2.67	17	05
H	3.17	27	30.17	27	30.17	0	17	05
I	2	30.17	32.17	32.5	34.5	2.33	0	0
J	2.67	32.17	34.8	34.5	41.67	7.33	33	11
K	6.17	30.17	36.34	30.17	36.34	0	17	05
L	5.5	36.34	41.84	36.34	41.84	0	5	25
M	3	41.84	44.84	41.84	44.84	0	33	11
N	4.33	44.84	49.17	44.84	49.17	0	17	05
O	4.33	44.84	49.17	49.17	52.5	3.33	36	11
P	3.17	49.17	52.34	49.17	52.34	0	17	05
Q	2.67	52.34	55.01	52.34	55.01	0	17	05

Figure 7. PERT Calculation Results Using POM QM For Windows Ver. 3.5

h. Critical Path Identification

Based on calculations using the PERT and CPM methods and explained in Figure 4.3, the critical path formed is A – B – C – D – E – F – H – K – L – M – N – P – Q, resulting in 55 days using the CPM method and 5.68 days or 56 days using the PERT method.

4. CONCLUSION

- a. Based on the results of the project network analysis, it was found that the network structure consists of eight activity paths. Through the application of the Activity on Node (AON) method, the network is depicted by 17 nodes. And 19 arrows representing dependencies between activities. Meanwhile, with the Activity on Arrow (AOA) method, the same network produces 15 nodes and 17 nodes, indicating different forms of representation but depicting logically equivalent project workflows.
- b. Based on the calculation results using the Critical Path Method (CPM), the optimal time for completing the construction of one house unit with two workers is 55 days, while using the Program Evaluation and Review Technique (PERT) method The optimal time



is 55.68 days or rounded to 56 days , with a 99.94% probability of completion within a 60-day deadline. Meanwhile, field observations show an actual completion time of 64 days. A comparison between the analysis results and actual conditions shows that through the application of the CPM and PERT methods, the project completion time was successfully streamlined up to 9 days faster than the actual implementation time. This proves that the use of both methods is effective in optimizing project duration planning and increasing the efficiency of work time in the field.

- c. The critical path formed is A – B – C – D – E – F – H – K – L – M – N – P – Q. The total time required with the CPM method is 55 days and with the PERT method is 55.68 days.

5. REFERENCES

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