Optimizing Project Scheduling Using CPM and PERT Methods (Case Study: Pejambon 8-Storey Flat, Central Jakarta)

Dewi Fauzah[1,*], Rafiq Setyawan[2], Anasya Arsita Laksmi[1], Sigit Adi Soebekti[3]

[1]Faculty of Defense Science and Technology, Defense University, Indonesia
[2]Faculty of Architectural Engineering, Mercu Buana University Jakarta, Indonesia
[3]Pusat Zeni Angkatan Darat

E-mail address: dewifauzaah@gmail.com

▪

ABSTRACT

Pejambon 8 Storey-Flat Construction Project is one of the annual work programs through the allocation of Government Islamic Securities (SBSN) funding for the 2023 Ministry of Finance of the Republic of Indonesia. In this research, the Critical Path Method and Project Evaluation and Review Methodology planning methods were used to implement project time management and increase effectiveness by making schedules empirically. The aim of applying the Critical Path Method and Project Evaluation and Review Methodology methods is to compare expectations with actual progress and avoid delays in critical path activities so that it can shorten the project period by considering costs. This research used the Critical Path Method and Project Evaluation and Review Methodology methods to evaluate projects. This method begins with compiling a project network diagram and collecting information related to time variations that can occur on projects in the field. Some of the results of the processed data produced are information related to the critical path of the project, probability of project scheduling, and variations in operational costs according to the total duration of work. The data required in this research include the physical progress report of the project, the project implementation schedule, curve S, and budget plan. The largest total operational labor costs for the Pejambon 8 Storey-Flat Construction Project in this study were IDR 11,034,695,000 with the fastest project completion time being 46 weeks.

Keywords: Network analysis, Project scheduling, PERT, CPM

1. INTRODUCTION

A construction project is a system that has a series of complex subsystems that require coordinated actions to achieve desired results, avoid delays, ensure quality, and avoid rework [1]. According to Scalisi 2021 [2], there are important stages in a construction project, namely pre-construction, site work, rough framing, exterior construction, MEP (mechanical, electrical, and plumbing) work, and finishing work. An important aspect in implementing a project is project management which plays a major role in two things that determine project success, namely the profits obtained and the timeliness of completion.

Managing time and costs is crucial in achieving project goals [3]. Project scheduling is a managerial actualization of time that shows the relationship of activities to one another and the entire project so that estimates can be made of work priorities and the realistic total duration required for each work activity. In a project, network analysis is needed as a scheduling technique that helps with the planning, implementation, and monitoring stages of the project. Scheduling is used as a tool for determining the activities required by a project in a certain sequence and time frame by taking into account the duration of the project plan and economic costs [4].

Under certain conditions, there are times when project stakeholders request accelerated completion of construction projects. The Pejambon 8-storey project is a State Building (BGN) that was built using APBN funding as a source of funding in one fiscal year. Therefore, project implementation is pegged at less than one year, namely 47 weeks. In order to optimize the scheduling of the Pejambon 8-storey project regarding project duration requirements, two types of project activity network analysis methods were used, namely the CPM (Critical Path Method) and PERT (Project Evaluation and Review Methodology).

2. THEORY AND METHODS

2.1 Theory

A. Network Analysis

The analysis is an investigative effort to see, observe, know, discover, understand, examine, classify, deepen, and interpret existing phenomena [5]. Network analysis is the main technique in management science which has basic characteristics in all projects, where the stages carried out in the project must be completed with clearly defined steps represented graphically in the form of a network or arrow diagram [6]. The two main network systems used in this research are as CPM and PERT.

B. Critical Path Method (CPM)

Critical Path Method (CPM) is a parallel stage model developed, to provide project control techniques [7]. CPM is usually used in conjunction with PERT. In this method, all project activities are clearly defined. Each activity is oriented as an arrow in an arrow diagram with a specific code [14]. Determination of the critical path is based on the longest duration range of interdependent activities [8]. Figure 1 explains the steps in which the Critical Path Method (CPM) method is implemented.

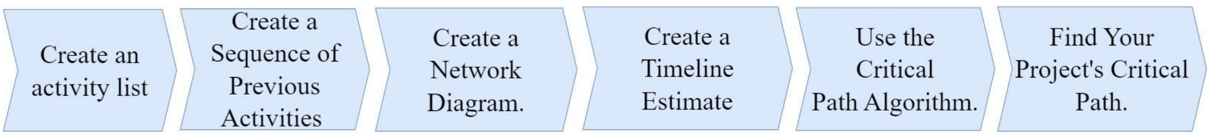

Figure 1. CPM Method Steps

C. Project Evaluation and Review Methodology (PERT)

PERT network analysis is a program that emphasizes delays in project activities and accelerates project completion [15]. In the PERT network system, time estimates are not as accurate as CPM. This method is generally used in construction projects that have a high level of uncertainty regarding time, engineering design, and final construction [8]. Based on [9], PERT network analysis is utilized to overcome the problem of activity time variability when scheduling projects. This method is recommended for all types of projects, because it is not only useful for large projects, but also has benefits in increasing project efficiency of all sizes [10]. Figure 2 explains the steps of the Project Evaluation and Review Methodology (PERT) [16].

Figure 2. PERT Method Steps

The PERT method requires analysis and calculations from primary data and secondary data that have been collected [13]. The following are several equations that are taken into account in the PERT method process, namely estimated time (Eq.1), standard deviation (Eq.2), variance (Eq.3), and probability of project implementation (Eq.4).

$$t_e = \frac{t_o + 4t_L + t_P}{6} \quad (1)$$

$$S_t = \frac{t_P - t_O}{6} \quad (2)$$

$$V = \left(\frac{t_P - t_O}{6}\right)^2 \quad (3)$$

$$Z = \left(\frac{t_d - t_e}{\sigma^2}\right) \quad (4)$$

In which:
t_e = estimated time
t_o = the optimistic time estimate
t_L = the most likely time estimate
t_P = the pessimistic time estimate
t_d = target duration
S_t = standard deviation
V = variance
Z = probability

2.2 Methods

This research uses quantitative and qualitative data. Qualitative data was obtained from field supervisor interview data collection techniques, as parties who are always in the field in real-time during project activities. Quantitative data is obtained from the planned duration variable. In addition, the primary data in this research was obtained from project documents, surveys, and interviews with related parties. Meanwhile, the research also utilizes secondary data such as literature reviews, previous reports, books, or other documents.

The object reviewed in this research is the Pejambon 8-storey project for the Indonesian Army, while the subject raised is rescheduling analysis as an optimization of project scheduling. This research adopts a quantitative method approach through the CPM and PERT planning methods obtained from literature studies. The data required in preparing this research includes the physical project progress report, the project implementation schedule, curve S, and budget plan.

3. RESULTS AND DISCUSSION

The Pejambon 8-storey flat construction project in Central Jakarta is one of the projects that use the 2023 State Revenue and Expenditure Budget (APBN) which is used to support army personnel facilities and planned to be established within a 48-week implementation period. The design of Pejambon 8-storey flat building can be seen in Figure 3.

Figure 3. 3D Design of the Pejambon Flat Plan, Central Jakarta

Project stage inventory is the process of collecting and compiling data regarding the sequence of work activities in a project. Table 1 shows the relationship between one activity and another activity at the Pejambon Flat Project, Central Jakarta.

Table 1. Inventory of Stages of Pejambon 8-storey Flat Project

Activity Code	Activity	Predecessor	Successor	Duration
1	Preparation	-	2	47
2	Ground Floor Structural Work	-	3	11
3	1st Floor Structural Work	1,2	4	7
4	2nd Floor Structural Work	3	5	7
5	3rd Floor Structural Work	4	6	7
6	4th Floor Structural Work	5	7	7
7	5th Floor Structural Work	6	8	7
8	6th Floor Structural Work	7	9	7
9	7th Floor Structural Work	8	10	7
10	8th Floor Structural Work	9	11	7

Activity Code	Activity	Predecessor	Successor	Duration
11	Ground Floor Finishing Work	3	12	4
12	Floor Finishing Work 1	11	13	7
13	2nd Floor Finishing Work	12	14	11
14	3rd Floor Finishing Work	13	15	11
15	4th Floor Finishing Work	14	16	11
16	5th Floor Finishing Work	15	17	11
17	6th Floor Finishing Work	16	18	11
18	7th Floor Finishing Work	17	19	11
19	Floor Finishing Work 8	18	21,22	6
20	Jogging Track Paving Block Road Work	21,22	-	9
21	Paving Roads and Channels Work	19	20	9
22	Uditch box channel Size 60.60.120 cm Work	19	20	9
23	Ground Tank + Pump House Construction Size 5 x 10.5 m	10	25	7
24	Pump House Construction Size 5 x 10.5 m	25	-	9
25	Septic Tank Construction Size 320x520x245 cm (2 units)	23	24	7
26	Plumbing Work	11	27,30	35
27	Firefighter Jobs	26	28	35
28	Electrical Work	27	29	35
29	Fire Alarm Work	28	-	35
30	Elevator Work	26	31	24
31	Air Conditioning Work	30	-	15
Total				**426**

It can be seen in Table 1, that the total duration of completion time for all work is 426 weeks, which is accumulated in 48 weeks of project completion with the constraints used in Activity on Arrow (AoA). The logical dependency relationships used in the Pejambon 8-storey flat project are Start to Start (SS), Finish to Start (FS), Start to Finish (SF), and Finish to Finish (FF), although variations of these relationships are not applied in the diagram CPM.

3.1 Critical Path Method (CPM) Analysis

The CPM diagram is a network that contains a systematic flow of activities carried out in project implementation to obtain information about the project's critical path. Based on [11], the critical path is a series of activities in a project that cannot be postponed and show inter-relationships with each other. In processing, the longest accumulated time duration is used as a benchmark for estimating the total duration of project completion as a whole. Figure 4 is a network diagram prepared using the CPM method which displays activities, predecessor work, subsequent work, and implementation time.

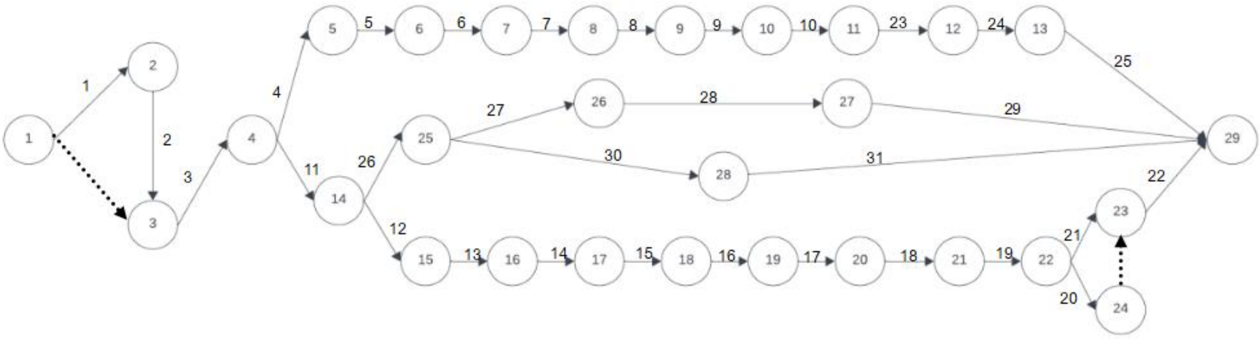

Figure 4. Network Diagram of The Pejambon 8-storey Project

From the processed data in Figure 4, the time duration is accumulated so that it can be seen that the critical path for the Pejambon 8-storey construction project is 1-2-3-4-14-25-26-27-29, with a total estimated duration of the entire work implementation is 209 weeks.

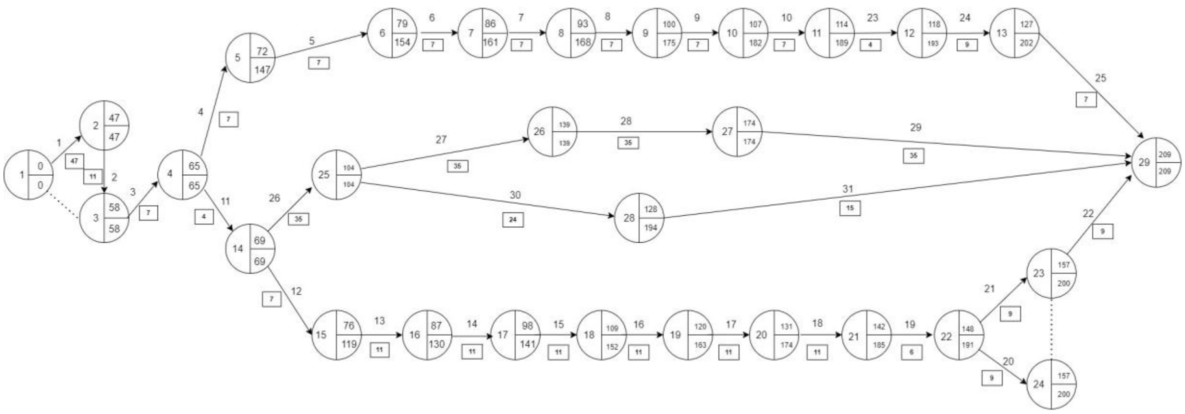

Figure 5. Network Diagram with Descriptions ES, EF, LS, LF

Table 2 below shows the recapitulation results of the CPM network diagram with information specifications ES (earliest start time for activity), EF (earliest finish time for activity), LS (latest allowable start time for activity), LF (latest allowable finish time for activity), and SL (total slack or float time for activity).

Table 2. Critical Path CPM Method

Activity Code	Route		Start		End		Duration
	i-node	j-node	ES	EF	LS	LF	
1	1	2	0	47	0	47	47
2	2	3	47	58	47	58	11
3	3	4	58	65	58	65	7
4	4	5	65	72	140	147	7
5	5	6	72	79	147	154	7

Activity Code	Route		Start		End		Duration
	i-node	j-node	ES	EF	LS	LF	
6	6	7	79	86	154	161	7
7	7	8	86	93	161	168	7
8	8	9	93	100	168	175	7
9	9	10	100	107	175	182	7
10	10	11	107	114	182	189	7
11	4	14	65	69	65	69	4
12	14	15	69	76	112	119	7
13	15	16	76	87	119	130	11
14	16	17	87	98	130	141	11
15	17	18	98	109	141	152	11
16	18	19	109	120	152	163	11
17	19	20	120	131	163	174	11
18	20	21	131	142	174	185	11
19	21	22	142	148	185	191	6
20	22	24	148	157	191	200	9
21	22	23	148	157	191	200	9
22	23	29	157	166	200	209	9
23	11	12	114	118	189	193	4
24	12	13	118	127	193	202	9
25	13	29	127	134	202	209	7
26	14	25	69	104	69	104	35
27	25	26	104	139	104	139	35
28	26	27	139	174	139	174	35
29	27	29	174	209	174	209	35
30	25	28	104	128	170	194	24
31	28	29	128	143	194	209	15

3.2. PERT (*Project Evaluation and Review Methodology*) Analysis

Analysis using the PERT method uses data from interviews with project field supervisors which includes information related to the list of activities, optimal time, most likely time, pessimistic time, standard deviation, and activity variance. The analysis uses Eq.1 to Eq.4 as stated previously. In this case, Eq.1 is a calculation of the estimated time, Eq.2 is a calculation to determine the standard deviation, Eq.3 is a calculation to determine the variance, and Eq.4 is a calculation to determine the probability of project implementation [6]. Furthermore, Table 3 shows the results of the PERT analysis that the author has carried out based on Eq.1 to Eq.3.

Table 3. Results of Time Analysis of The Pejambon 8-storey Project

Activity Code	Duration (Week)			Estimated Time (Te)	Deviation	Variance (V)
	Fast	Normal	Slow			
1	43	45	47	45	39,83	1586,69
2	7	9	11	9	9,83	96,69
3	5	6	7	6	6,17	38,03
4	5	6	7	6	6,17	38,03
5	5	6	7	6	6,17	38,03
6	5	6	7	6	6,17	38,03
7	5	6	7	6	6,17	38,03
8	5	6	7	6	6,17	38,03
9	5	6	7	6	6,17	38,03
10	5	6	7	6	6,17	38,03
11	5	6	7	6	6,17	38,03
12	5	6	7	6	6,17	38,03
13	9	10	11	10	9,50	90,25
14	9	10	11	10	9,50	90,25
15	9	10	11	10	9,50	90,25
16	9	10	11	10	9,50	90,25
17	9	10	11	10	9,50	90,25
18	9	10	11	10	9,50	90,25
19	5	6	6	6	5,17	26,69
20	7	9	9	9	7,83	61,36
21	7	8	9	8	7,83	61,36
22	5	7	9	7	8,17	66,69
23	5	6	7	6	6,17	38,03
24	6	8	9	8	8,00	64,00
25	5	6	7	6	6,17	38,03
26	32	34	35	34	29,67	880,11
27	32	34	35	34	29,67	880,11
28	32	34	35	34	29,67	880,11
29	31	34	35	34	29,83	890,03
30	21	24	24	24	20,50	420,25
31	11	14	15	14	13,17	173,36
TOTAL	**353**	**398**	**429**	**398**	**370,17**	**7.085,31**

Standard deviation and variance are parameters in the PERT method to characterize the degree of uncertainty associated with estimating activity duration [17]. Variance is used to measure how far the data is spread and the average value [18] and expresses the uncertainty of the specified time estimate [13]. The greater the variance, the greater the uncertainty. So, the most uncertain time estimate is activity with code 1, while activities with codes 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 23 are activities with more certain time estimates.

Standard deviation is the square root of the variance value to measure the variability or uncertainty of a set of data [19]. From the calculation results in the table, it can be seen that the standard deviation is 370.17.

In the PERT method, the concept of probability of achieving scheduling targets is used to determine the potential or probability number of project implementation within the estimated time [12]. Based on equation Eq.4 and using the normal distribution table, the probability value for project implementation using the PERT method analysis results is 2.28 or the same as 0.9887 when seen in the cumulative normal distribution table, so ($T \leq 429$) has a probability percentage of 98.87 %.

$$\text{Fastest time (a)} = te - 3\sqrt{V} = 398 - (3 \times 9.17) = 370.5 \text{ weeks}$$

$$\text{Longest time (b)} = te + 3\sqrt{V} = 398 + (3 \times 9.17) = 425.5 \text{ weeks}$$

A gantt chart is a schedule that is graphically created with left-to-right horizontal bars, enabling planning and tracking of project schedules [20]. According to the results of data testing using the PERT method, the Gantt Chart for construction activities for the Pejambon 8-storey project, Central Jakarta is shown in Table 4 below three-time-plans were obtained consisting of a fast duration of 46 weeks, a normal duration of 47 weeks, and a slow duration of 48 weeks.

Table 4. Gantt Chart for The Pejambon 8-storey Construction Project, Central Jakarta

No	Duration	
1	Optimistic	43
	Most Likely	45
	Pessimistic	47
2	Optimistic	7
	Most Likely	9
	Pessimistic	11
3	Optimistic	5
	Most Likely	6
	Pessimistic	7
4	Optimistic	5
	Most Likely	6
	Pessimistic	7
5	Optimistic	5
	Most Likely	6
	Pessimistic	7
6	Optimistic	5
	Most Likely	6
	Pessimistic	7
7	Optimistic	5
	Most Likely	6
	Pessimistic	7
8	Optimistic	5
	Most Likely	6
	Pessimistic	7
9	Optimistic	5
	Most Likely	6
	Pessimistic	7
10	Optimistic	5
	Most Likely	6
	Pessimistic	7
11	Optimistic	5
	Most Likely	6
	Pessimistic	7
12	Optimistic	5
	Most Likely	6
	Pessimistic	7
13	Optimistic	9
	Most Likely	10
	Pessimistic	11
14	Optimistic	9
	Most Likely	10
	Pessimistic	11
15	Optimistic	9
	Most Likely	10
	Pessimistic	11
16	Optimistic	9
	Most Likely	10
	Pessimistic	11
17	Optimistic	9
	Most Likely	10
	Pessimistic	11
18	Optimistic	9
	Most Likely	10
	Pessimistic	11
19	Optimistic	5
	Most Likely	6
	Pessimistic	6
20	Optimistic	7
	Most Likely	9
	Pessimistic	9
21	Optimistic	7
	Most Likely	8
	Pessimistic	9
22	Optimistic	5
	Most Likely	7
	Pessimistic	9
23	Optimistic	5
	Most Likely	6
	Pessimistic	7
24	Optimistic	6
	Most Likely	8
	Pessimistic	9
25	Optimistic	5
	Most Likely	6
	Pessimistic	7
26	Optimistic	32
	Most Likely	34
	Pessimistic	35
27	Optimistic	32
	Most Likely	34
	Pessimistic	35
28	Optimistic	32
	Most Likely	34
	Pessimistic	35
29	Optimistic	31
	Most Likely	34
	Pessimistic	35
30	Optimistic	21
	Most Likely	24
	Pessimistic	24
31	Optimistic	11
	Most Likely	14
	Pessimistic	15

A comparison of operational costs that focus on the number of workers with the average costs incurred is presented in Table 5 as follows. The fast duration produces a total cost of IDR 11,034,695,000, the normal duration produces a total cost of IDR 10,814,545,000, and the slow duration produces a total cost of IDR 10,593,100,000. The faster the project is completed, the higher the operational costs.

Table 5. Operational Costs for Each Duration

Week	Total Manpower			Total Cost		
	Optimistic	Most Likely	Pessimistic	Optimistic	Most Likely	Pessimistic
1	19	19	18	IDR 24,605,000	IDR 24,605,000	IDR 23,310,000
2	41	40	39	IDR 53,095,000	IDR 51,800,000	IDR 50,505,000
3	41	40	39	IDR 53,095,000	IDR 51,800,000	IDR 50,505,000
4	41	40	39	IDR 53,095,000	IDR 51,800,000	IDR 50,505,000
5	41	40	39	IDR 53,095,000	IDR 51,800,000	IDR 50,505,000
6	55	54	52	IDR 71,225,000	IDR 69,930,000	IDR 67,340,000
7	60	59	57	IDR 77,700,000	IDR 76,405,000	IDR 73,815,000
8	67	66	64	IDR 86,765,000	IDR 85,470,000	IDR 82,880,000
9	71	70	68	IDR 91,945,000	IDR 90,650,000	IDR 88,060,000
10	71	70	68	IDR 91,945,000	IDR 90,650,000	IDR 88,060,000
11	81	79	77	IDR 104,895,000	IDR 102,305,000	IDR 99,715,000
12	81	79	77	IDR 104,895,000	IDR 102,305,000	IDR 99,715,000
13	81	79	77	IDR 104,895,000	IDR 102,305,000	IDR 99,715,000
14	81	79	77	IDR 104,895,000	IDR 102,305,000	IDR 99,715,000
15	85	83	81	IDR 110,075,000	IDR 107,485,000	IDR 104,895,000
16	99	97	95	IDR 128,205,000	IDR 125,615,000	IDR 123,025,000
17	117	115	112	IDR 151,515,000	IDR 148,925,000	IDR 145,040,000
18	123	121	118	IDR 159,285,000	IDR 156,695,000	IDR 152,810,000
19	138	135	132	IDR 178,710,000	IDR 174,825,000	IDR 170,940,000
20	137	134	131	IDR 177,415,000	IDR 173,530,000	IDR 169,645,000
21	146	143	140	IDR 189,070,000	IDR 185,185,000	IDR 181,300,000
22	157	154	150	IDR 203,315,000	IDR 199,430,000	IDR 194,250,000
23	185	181	177	IDR 239,575,000	IDR 234,395,000	IDR 229,215,000
24	188	184	180	IDR 243,460,000	IDR 238,280,000	IDR 233,100,000
25	188	184	180	IDR 243,460,000	IDR 238,280,000	IDR 233,100,000
26	192	188	184	IDR 248,640,000	IDR 243,460,000	IDR 238,280,000
27	192	188	184	IDR 248,640,000	IDR 243,460,000	IDR 238,280,000
28	216	212	207	IDR 279,720,000	IDR 274,540,000	IDR 268,065,000
29	240	235	230	IDR 310,800,000	IDR 304,325,000	IDR 297,850,000
30	240	235	230	IDR 310,800,000	IDR 304,325,000	IDR 297,850,000
31	240	235	230	IDR 310,800,000	IDR 304,325,000	IDR 297,850,000
32	202	198	193	IDR 261,590,000	IDR 256,410,000	IDR 249,935,000
33	206	202	197	IDR 266,770,000	IDR 261,590,000	IDR 255,115,000
34	279	273	267	IDR 361,305,000	IDR 353,535,000	IDR 345,765,000
35	279	273	267	IDR 361,305,000	IDR 353,535,000	IDR 345,765,000
36	279	273	267	IDR 361,305,000	IDR 353,535,000	IDR 345,765,000
37	251	246	240	IDR 325,045,000	IDR 318,570,000	IDR 310,800,000
38	262	257	251	IDR 339,290,000	IDR 332,815,000	IDR 325,045,000
39	418	410	298	IDR 541,310,000	IDR 530,950,000	IDR 385,910,000
40	410	297	290	IDR 530,950,000	IDR 384,615,000	IDR 375,550,000
41	413	404	293	IDR 534,835,000	IDR 523,180,000	IDR 379,435,000
42	412	403	292	IDR 533,540,000	IDR 521,885,000	IDR 378,140,000
43	409	296	289	IDR 529,655,000	IDR 383,320,000	IDR 374,255,000
44	409	296	289	IDR 529,655,000	IDR 383,320,000	IDR 374,255,000
45	302	296	289	IDR 391,090,000	IDR 383,320,000	IDR 374,255,000
46	302	296	289	IDR 391,090,000	IDR 383,320,000	IDR 374,255,000
47		316	309		IDR 409,220,000	IDR 400,155,000
48			308			IDR 398,860,000
TOTAL	8521	8351	8180	IDR 11,068,365,000	IDR 10,814,545,000	IDR 10,593,100,000

The network diagram shown in Figure 6 shows the result of the PERT data processing. Additionally, the tabulation of the ES, EF, LS, LF, and Slack calculation results is shown in Table 6.

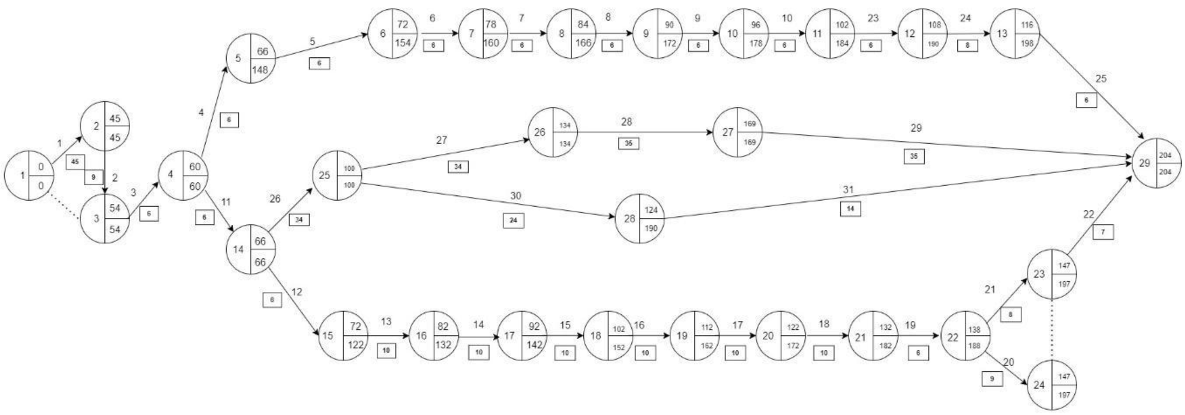

Figure 6. Network diagram with estimated time calculation results for ES, EF, LS, LF

Table 6. Results of analysis of the timing of The Pejambon 8-storey Project

Activity	Route		Start		Finish		Duration
	i-node	j-node	ES	EF	LS	LF	
1	1	2	0	45	0	45	45
2	2	3	45	54	45	54	9
3	3	4	54	60	54	60	6
4	4	5	60	66	142	148	6
5	5	6	66	72	148	154	6
6	6	7	72	78	154	160	6
7	7	8	78	84	160	166	6
8	8	9	84	90	166	172	6
9	9	10	90	96	172	178	6
10	10	11	96	102	178	184	6
11	4	14	60	66	60	66	6
12	14	15	66	72	116	122	6
13	15	16	72	82	122	132	10
14	16	17	82	92	132	142	10
15	17	18	92	102	142	152	10
16	18	19	102	112	152	162	10
17	19	20	112	122	162	172	10
18	20	21	122	132	172	182	10
19	21	22	132	138	182	188	6
20	22	24	138	147	188	197	9
21	22	23	138	146	189	197	8
22	23	29	147	154	197	204	7
23	11	12	102	108	184	190	6
24	12	13	108	116	190	198	8
25	13	29	116	122	198	204	6

Activity	Route		Start		Finish		Duration
	i-node	j-node	ES	EF	LS	LF	
26	14	25	66	100	66	100	34
27	25	26	100	134	100	134	34
28	26	27	134	169	134	169	35
29	27	29	169	204	169	204	35
30	25	28	100	124	166	190	24
31	28	29	124	138	190	204	14

The research results show that the potential for accelerating project duration will have an impact on the total project operational costs. The faster the project duration, the higher the operational costs. With this research, it is hoped that it can optimize the duration of project implementation, minimize delays, and become a reference for future projects.

4. CONCLUSIONS

Based on the results and discussions, the conclusions of this research are:

1. Based on the results of the analysis using a network diagram, there are four paths, namely path 1-2-3-4-5-6-7-8-9-10-11-12-13-29, path 1-2- 3-4-14-25-26-27-29, path 1-2-3-4-14-25-28-29, and path 1-2-3-4-14-15-16-17-18 -19-20-21-22-23-24-29.
2. Among the four arranged routes, route 1-2-3-14-25-26-27-29 is the critical route that explains the activity trajectory that most determines the completion time of the entire Pejambon 8-storey construction project, with a total completion time work activity of 209 weeks.
3. According to PERT data processing, it can be concluded that the probability of project scheduling with a total time for all activities of less than 398 weeks is 14.06%, with the fastest value being 370.5 weeks and the late time being 425.5 weeks of the total the start of overall project activity was 429 weeks.
4. According to data processing using the CPM and PERT methods, three total time plans for project work can be planned, namely work with a fast duration (46 weeks) with a total operational labor cost of IDR 11,034,695,000, normal duration (47 weeks) with a total labor operational costs worth IDR 10,814,545,000, and slow duration (48 weeks) with total labor operational costs worth IDR 10,593,100,000.
5. The faster the duration of the work, the more operational labor costs will increase, which is in line with the increase in the number of personnel.

5. ACKNOWLEDGEMENTS

We would like to express our sincere thanks for Pusat Zeni Angkatan Darat’s invaluable contribution to this project. Pusat Zeni Angkatan Darat's provision of data and guidance was very instrumental in helping us complete this research.

REFERENCES

[1] Mahyuddin. (2023). "Manajemen Proyek Konstruksi,". Available : https://www.researchgate.net/publication/374022900_Manajemen_Proyek_Konstruksi [Accessed December 12, 2023].

[2] Scalisi, Tom. (2021). "Stages of a Construction Project & Why They Matter,". America: Levelset. [Accessed December 12, 2023] Availaible : http://surl.li/ozrdt. [Accessed December 12, 2023].

[3] Iriyanto, Santje M., and Sopater Yosep Oktovianus Hommy. (2017) "Analisa Perencanaan Waktu Dengan Metode PERT Pada Pelaksanaan Proyek Pembangunan Gedung Negara Provinsi." Jurnal Portal Sipil 6.2 : 10-28. Available : https://ojs.ustj.ac.id/sipil/article/download/217/148 [Accessed December 12, 2023].

[4] Kolisch, R., & Padman, R. 2001. "An integrated survey of deterministic project scheduling". Omega, 29(3): 249-272. Avalaible : https://www.sciencedirect.com/science/article/pii/S0305048300000463 [Accessed December 12, 2023].

[5] Wahyuni, J., Paranthy, Y. W., & Wanto, A. 2018. "Analisis Jaringan Saraf Dalam Estimasi Tingkat Pengangguran Terbuka Penduduk Sumatera Utara". Jurnal Infomedia: Teknik Informatika, Multimedia & Jaringan, 3(1): 18-24. Avalaible : http://e-jurnal.pnl.ac.id/infomedia/article/view/624 [Accessed December 14, 2023 .

[6] Punmia, B. C., & Khandelwal, K. K. 2002. "Project planning and control with PERT & CPM". Firewall media. Avalaible : https://books.google.com/books?hl=id&lr=&id=wtwMj_wnvgEC&oi=fnd&pg=PA1&dq=Project+planning+and+control+with+PERT+%26+CPM&ots=x85jt4oRCN&sig=1td-FL_QmmhDTiknKTCfcQD-Ao4 [Accessed December 14, 2023].

[7] Syawal, M. 2019. "Perencanaan Jaringan Kerja Perakitan Lambung Kapal Ferry 300 GT Dengan Menggunakan CPM (Critical Path Method)". (Doctoral dissertation, Universitas Hasanuddin). Avalaible : http://repository.unhas.ac.id/id/eprint/6461/ [Accessed December 14, 2023] .

[8] Bayraktar, M. E., Arif, F., Hastak, M., & Gad, N. A. 2012. "Judiciary's use of the critical path method to resolve construction claims. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction", 4(1): 10-16. Avalaible : https://ascelibrary.org/doi/abs/10.1061/(ASCE)LA.1943-4170.0000079 [Accessed December 16, 2023].

[9] Danyanti, E., & Sudaryanto, B. 2011. "Optimalisasi Pelaksanaan Proyek Dengan Metode PERT dan CPM (Studi Kasus Twin Tower Building Pasca Sarjana Undip)". (Doctoral dissertation, Universitas Diponegoro). Avalaible : http://eprints.undip.ac.id/26423 [Accessed December 12, 2023].

[10] Handoko, T.H. 1999. "Dasar-dasar Manajemen Produksi Dan Operasi", Edisi Pertama. BPFE : Yogyakarta.Avalaible : https://library.stiemifdasubang.ac.id/index.php?p=show_detail&id=357&keywords= [Accessed December 12, 2023].

[11] Heizer, J. dan Render, B. 2006. Manajemen Operasi, Edisi 7. Jakarta: Salemba Empat.

[12] Wicaksono, Mochammad Hendy; Sugandi, R. Machmud; Alfianto, Imam. "Pengendalian Durasi Optimal pada Pembangunan Myze Hotel Sumenep Menggunakan CPM dan Metode PERT". Bentang: Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil, 2024, 12.1: 49-62. Avalaible : https://jurnal.unismabekasi.ac.id/index.php/bentang/article/view/7323 [Accessed December 12, 2023].
[13] Habibi, F., Birgani, O., Koppelaar, H., & Radenović, S. 2018. "Using fuzzy logic to improve the project time and cost estimation based on Project Evaluation and Review Technique (PERT)". Journal of Project Management, 3(4), 183-196. Avalaible : http://m.growingscience.com/beta/jpm/2778-using-fuzzy-logic-to-improve-the-project-time-and-cost-estimation-based-on-project-evaluation-and-review-technique-pert.html [Accessed December 12, 2023].
[14] Llach i Porcell, G. 2021. "Optimization of the PERT/CPM project management methodology by implementing the Lean and Agile philosophies". Avalaible : Avalaible : https://diposit.ub.edu/dspace/handle/2445/204905 [Accessed January 19, 2023]
[15] Taner, Z. T.; Soyluk, A.; Ilerisoy, Z. Y. "Comparison of the Benefits of CPM and PERT to Project Partners on Different Projects". Avalaible : https://www.researchgate.net/profile/Zafer-Tarik-Taner/publication/364753742_Comparison_of_the_Benefits_of_CPM_and_PERT_to_Project_Partners_on_Different_Projects/links/63595cc712cbac6a3efb1499/Comparison-of-the-Benefits-of-CPM-and-PERT-to-Project-Partners-on-Different-Projects.pdf [Accessed January 19, 2023]
[16] Cynthia, O. U. 2020. Implementation of Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM): A Comparative Study. International Journal of Industrial and Operations Research, 3(004). Avalaible : https://pdfs.semanticscholar.org/a9b7/b95fb5f53a9e5e507214a6a411c3de88e926.pdf [Accessed January 19, 2023]
[17] Neely, L. 2017. "Project Scheduling Disputes: Expert Characterization and Estimate Aggregation" (Doctoral dissertation). Avalaible : https://drum.lib.umd.edu/handle/1903/19380 [Accessed January 19, 2023]
[18] Bangphan, S., Bangphan, P., & Phanphet, S. 2019. "Application of project scheduling in production process for paddy cleaning machine by using PERT and CPM techniques". Expert systems in finance: Smart financial applications in big data environments, 188. Avalaible : https://books.google.com/books?hl=id&lr=&id=9KeaDwAAQBAJ&oi=fnd&pg=PA188&dq=Variance+is+used+to+measure+how+far+the+data+is+spread+and+the+average+value.+*cpm+pert*&ots=WgKzjm-JKV&sig=NVrJI9qH1UdoQa90MC_pjCWyApQ [Accessed January 19, 2023]
[19] Osborne, J. 2019. Improving your data transformations: Applying the Box-Cox transformation. Practical Assessment, Research, and Evaluation, 15(1), 12.Avalaible : https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1238&context=pare. [Accessed January 20, 2023]

[20] Sharon, A., & Dori, D. 2017. "Model-Based Project-Product Lifecycle Management and Gantt Chart Models: A Comparative Study". Systems engineering, 20(5), 447-466. Avalaible : https://www.researchgate.net/profile/Dov-Dori/publication/317400713_Model-Based_Project-Product_Lifecycle_Management_and_Gantt_Chart_Models_A_Comparative_Study/links/59e7162c0f7e9b13acac6e7e/Model-Based-Project-Product-Lifecycle-Management-and-Gantt-Chart-Models-A-Comparative-Study.pdf [Accessed January 20, 2023]