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Cost and Time Control of Construction Projects due to Delays in Work Progress based on POM-QM

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Abstract:- Proper and planned construction management in managing time and costs which is a benchmark in the success of a project. A construction project, in its implementation, often finds a condition where optimization must be carried out precisely and quickly in meeting the time demands of a contract which reflects the wishes of an owner as a provider of funds. Therefore, it is necessary to use the Time and Cost Prediction Application for Construction Projects to be able to estimate the time and costs required so that the project can be completed on time. One method that can be used is the POM-QM Based Linear Programming method. This research is focused on knowing: [1]Optimization of project completion costs; [2]Optimization of project completion time; [3]Opportunity or probability of project completion time. The data used is from the Aspena Residence-Tangerang Apartment Project, in terms of architectural work from the 5th floor to the 11th floor. The results of this study are: [1]Optimization of the acceleration time [in] completing this project is 56 weeks (normal time 99 weeks); [2]Crashing costs (acceleration optimization costs) obtained amounting to IDR 1,624,910,000; [3]Opportunities or time probabilities with a value of Z = 3.063 and a probability of 99.8%. From this research, the researcher hopes that this research can be useful for related parties as material for consideration in planning and evaluating project completion time, as well as for other new projects.

Keywords:- *Cost and Time Optimization; POM-QM; Aspena Apartments; Odds or Time Probability.*

I. INTRODUCTION

A construction project, in its implementation, often finds a condition where optimization must be carried out precisely and quickly in meeting the time demands of a contract which reflects the wishes of an owner as a provider of funds. This is certainly done effectively (doing the right things) and efficiently (doing the right things) by not forgetting the quality and use of work costs. Even though an activity has been planned as well as possible, it still contains uncertainty that later it will go completely according to plan. Risk is always present in construction projects and often causes schedule delays or cost increases (Wang & Chou, 2003).

Such as the research that is being examined on the Aspena Residence Apartment Project in Tangerang, where the actual progress is 72.137% of the progress planned of 81.309%, resulting in a minus deviation or delay in project progress of -9.172%.

Therefore, a project control planning method is needed, one of the methods that can be used is the POM-QM Software.The POM-QM program is a computer program that is used to solve quantitative management problems in production and operations. Ease of operation makes POM-QM for Windows V.5.2 an alternative application to help decision making.

Table 1: Project Problem Identification

No	Problem Identification	Causes of Problems
1	Reducing the construction of the number of floors of apartments from 12 floors to 11 floors;	Customer/Tenant targets not achieved
2	Delays in work progress that experience Deviations; -9.172%	Unstable work productivity; lack of control over labor resources and material use

This research aims to:

- To determine the optimization of the time and cost of project completion.
- To determine the number of work items that can be processed time/crashing activities in the network, to reduce time on the critical path.
- To determine the opportunity or probability of project completion time.

II. METHODOLOGY

Based on the background, the formulation of the problem and the objectives to be achieved, this research is of the nature of Statistical Analysis where to answer the formulation of the problem a concept or theory is used so that a hypothesis is formulated how to analyze Cost and Time Optimization due to delays in work on the Aspena Residence Apartment Project-Tangerang. This type of research is quantitative research, namely research that emphasizes numerical data (numbers) processed by statistical methods (Azwar, 2007: 5).

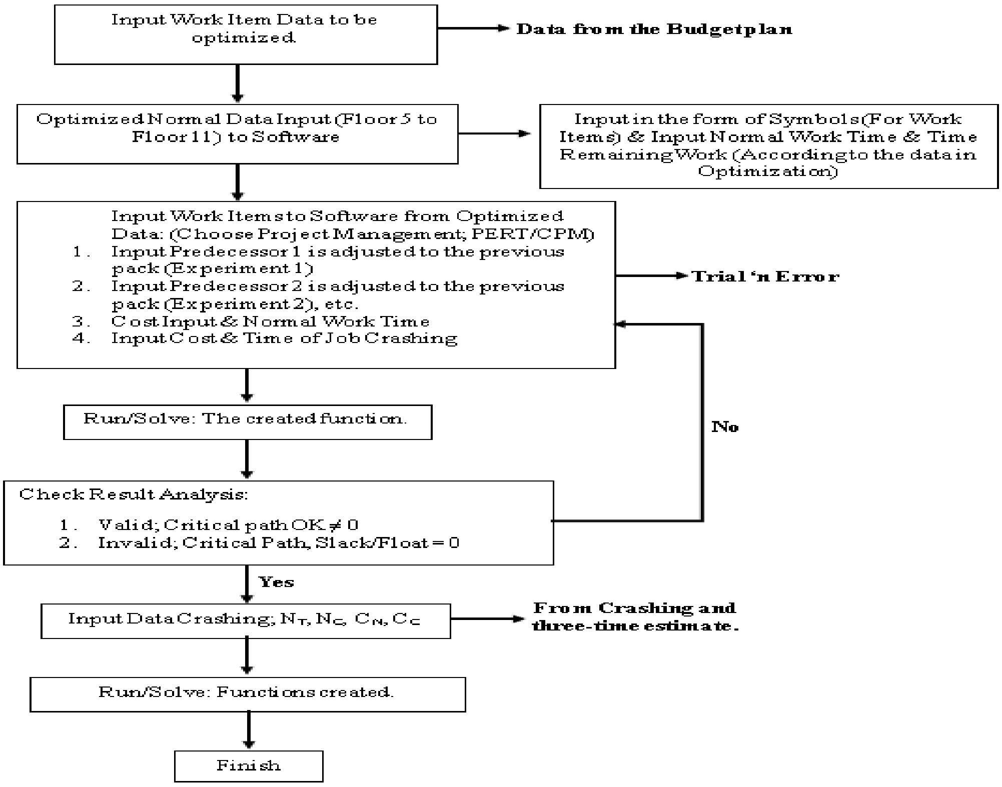


Fig. 1: Research Model

In this study, the object studied was architectural work (5th floor to 11th floor). Primary data collection is carried out by collecting project data such as the Cost Budget Plan (RAB), S Curve, Work Unit Prices, which have been planned, reports on the physical progress of project work. And there are 32 work items made in the form of symbols from each work item.

The data input and output methods were made using the POM-QM Software for Windows V.5.2. Where the POM-QM project management analysis uses **the PERT** (*Program Evaluation and Review Technique)* method. PERT is a project scheduling method that is engineered to deal with high uncertainty in the duration of project activities by taking an approach that assumes that the duration of activities is influenced by many factors so that a range is applied using three estimates. The three estimates are the *pessimistic time (tp), the most likely or most likely* estimate time (tm), and the *optimistic time* (to) .

To determine the probability/probability, this study uses the **PERT probability theory,**which explains:

- Distribution curve and variablesThe three estimates are the *pessimistic time* (b), the most likely or *most likely* forecast time (m), and the *optimistic time* (a) .
- Standard deviation and variance
- Completion schedule targets

$$Z=\frac{T(d)-TE}{S}$$

Information:
Z = Probability (chance)
T(d) = Deadline
TE = Expected Completion Time
S = Standard Deviation Total Variance

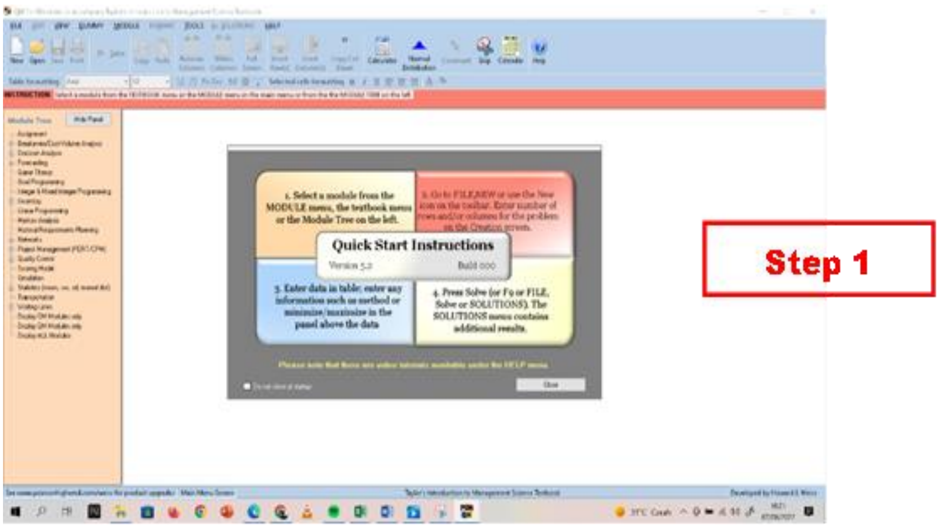
After the value of z is obtained, the probability number can be searched using the Appendix table of the Cumulative Normal Distribution (Z). The probability results obtained indicate the probability that the project will be completed within the planned timeframe.

Table 2: Symbol of Project Activity (Floor 5 to Floor 11)

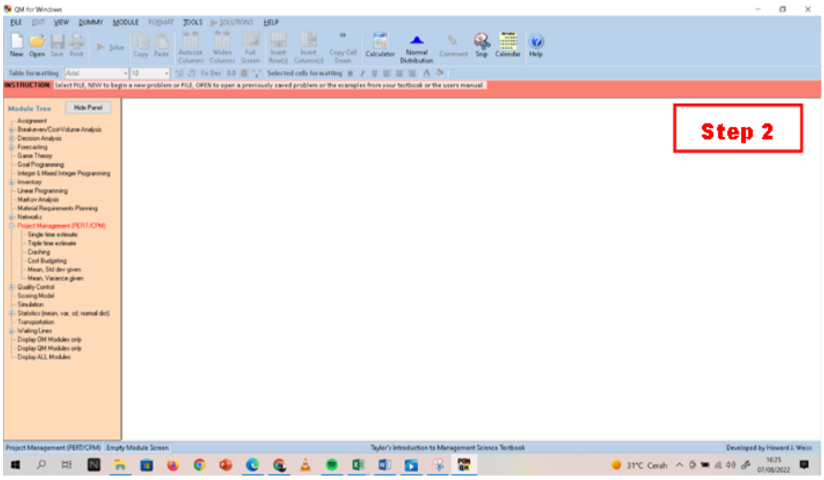
No	Work Activity	Symbol
1	Wall Waterproffing Coating	A1
2	Waterproffing Membrane	A2
3	Wall Ceramics	B1
4	Gypsum ceiling	C1
5	GRC (Glass Reinforced Concrete) Board	C2
6	GRC WR (Water resistance) Board	C3
7	Shadow Lines	C4
8	ACP (Alumunium Composite Panel)	D1
9	Ceramic Floor 60x60 cm in Units	E1
10	Ceramic Floor 30x30 cm in Balcony & Toilet	E2
11	Ceramic Lobby Elevator	E3
12	Balcony Ceramic Plint & Panel Room	F1
13	Ceramic plinth HT (Homogenus tile) 10/60 cm	F2
14	Ceramic Plint HT 10/30 cm (balcony unit)	F3
15	Wooden Door (Unit) P1	G1
16	PB1 Iron Door	G2
17	Fire Door PB2A	G3
18	Door R Panel PB3	G4
19	GR1 ventilation (emergency stairway & trash room)	G5
20	PS1 Shafts	G6
21	PS2 Shafts	G7
22	Aluminum P3 door (balcony)	G8
23	P2 UPVC door (toilet)	G9
24	Studio Unit Aluminum Window	G10
25	Aluminum Window 1,800x1,150 cm 1 BR (unit)	G11
26	Aluminum Window 1,200x1,150 cm 1 BR (unit)	G12
27	J4 Window Aluminum Grill Jalus 800x1,150 cm In Corridor	G13
28	J5 Aluminum windows uk 2,400x1,150 cm in Unit 1 BR	G14
29	Interior Wall Paint	H1
30	Facade Paint	H2
31	Exterior Paint	H3
32	Ceiling Paint	H4

III. OPERATIONAL STEPS USING QM FOR WINDOWS (POM-QM)

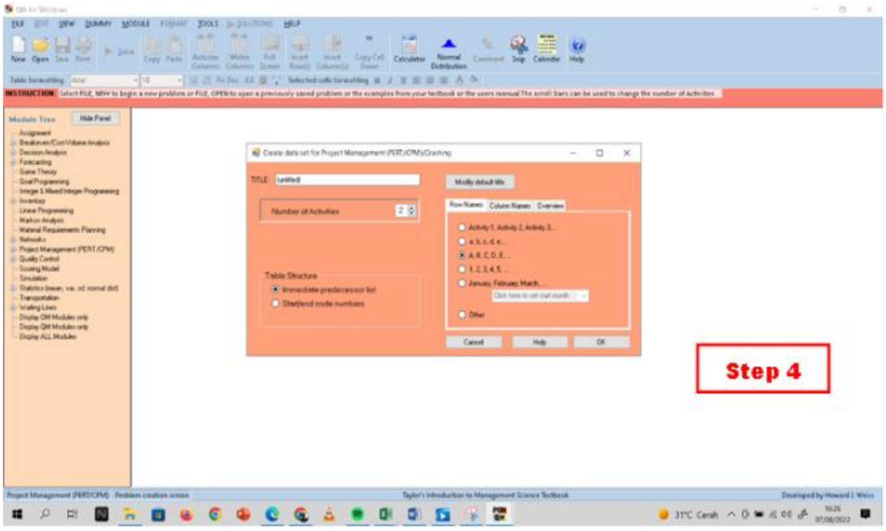
- Open the program then click Module



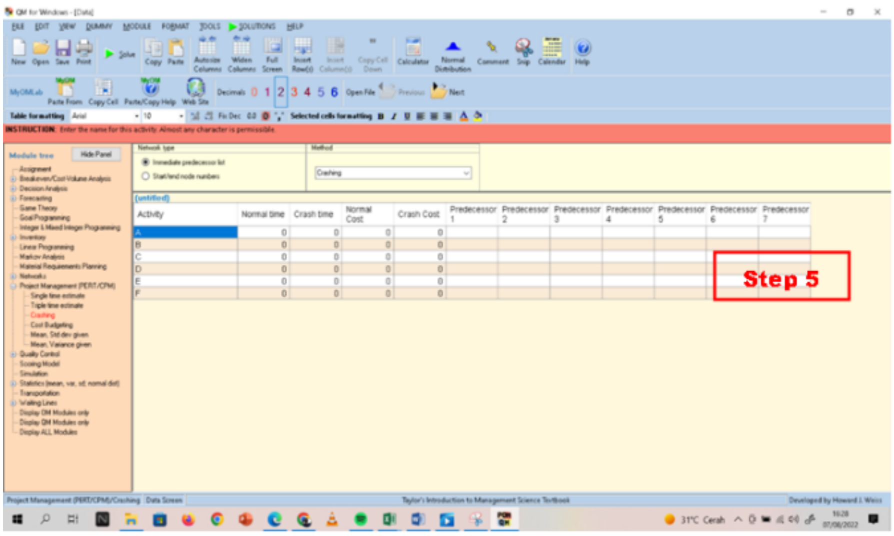
- Select Project Management (PERT/CPM)



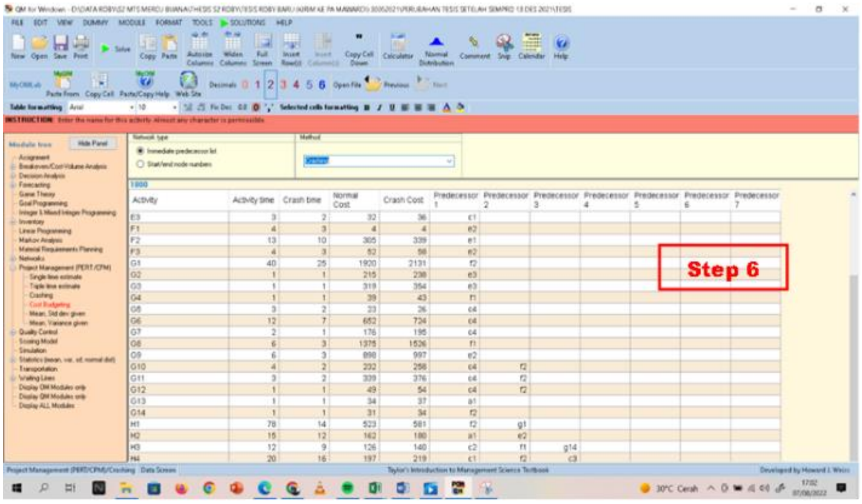
- Click Files
- Click New and move the cursor to the crashing menu.



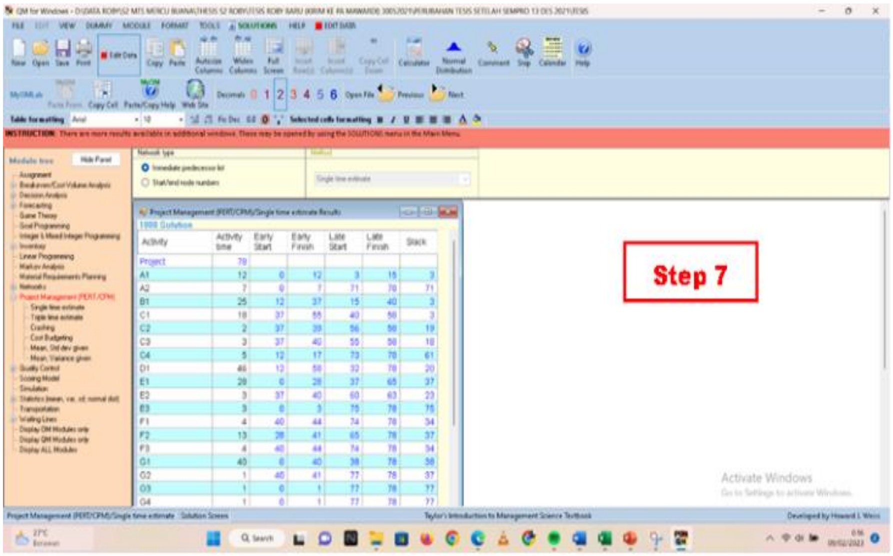
- Click Crashing and click Ok. Input data on the number of activities



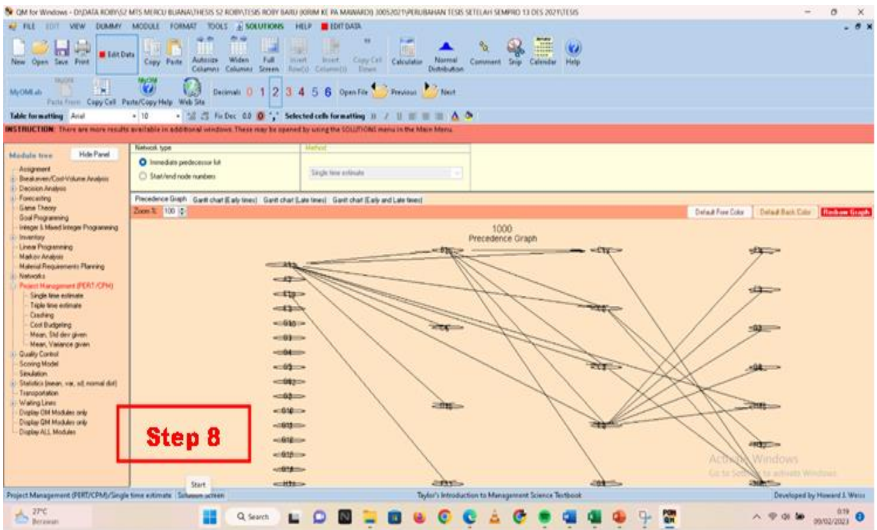
- Start working with input in the column activity, normal time, crash time, normal cost, crash cost and predecessors.



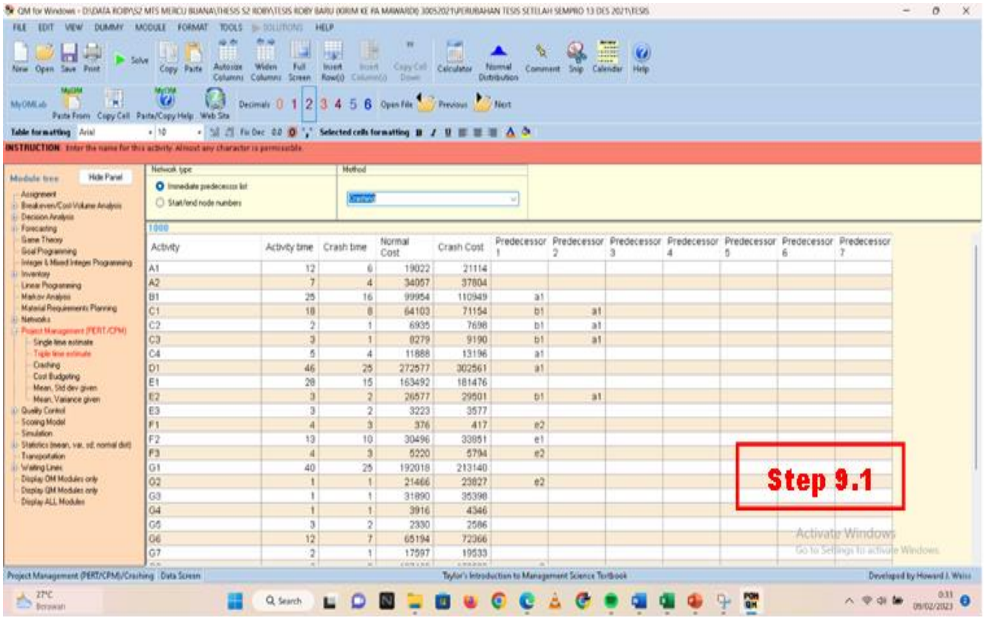
- After inputting data, click the solve menu at the top left of the application window.

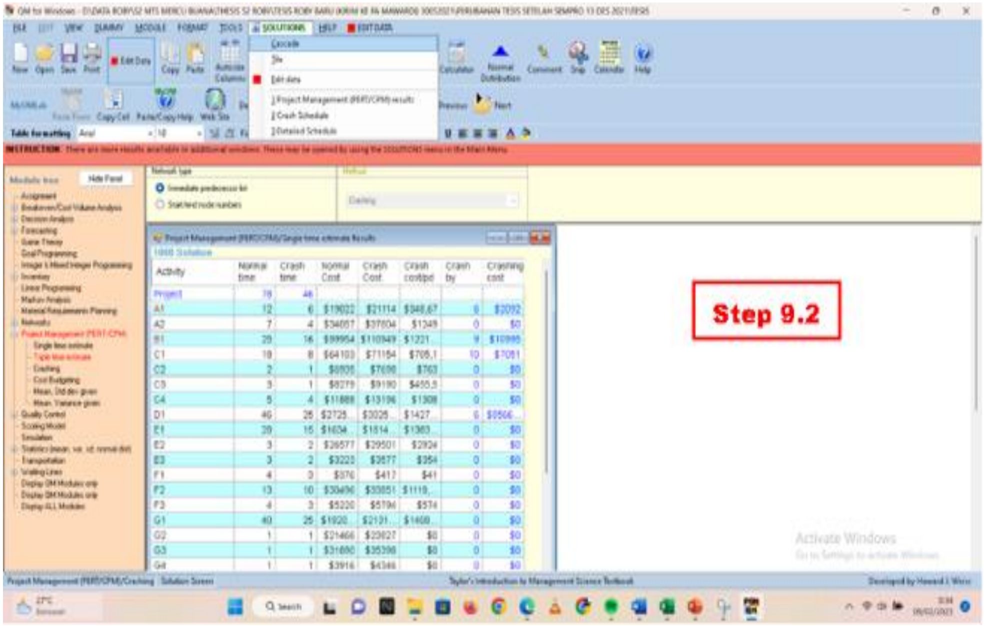


- On the solution menu, select Chart, so you get an example of a chart diagram.



- Calculating crashing selected crashing sub menu (For crashing and three-time estimate can be done by clicking on the menu crashing and three-time estimate)





IV. RESULTS AND DISCUSSION

This chapter will also describe in detail the optimization of project time and costs using the crashing method. Data analysis was carried out by inputting data directly into the Microsoft Excel program, which includes three stages, namely:

A. Develop a project schedule and cost plan (baseline) .

- The work standard that will be set is based on the SNI (*Indonesian National Standard*) Worker Unit Analysis.
- Budget plan of project implementation (Architect Work from 5th floor to 11th floor).
- The latest condition of the progress report for September 2021, is to find out how much the project is experiencing delays in progress.
- Weekly report : the last 4 months (from September to December 2021) to find out the number of workers in each item of architectural work that will be optimized.

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Table 3: Initial Conditions; Actual Progress Project

No	Work Activity	Symbol	Actual Progres	Remaining Progress	Normal Time Weeks	Deadline Time Weeks
1	Wall Waterprofing Coating	A1	30%	70%	12	6
2	Waterproffing Membrane	A2	30%	70%	7	4
3	Wall Ceramics	B1	20%	80%	25	16
4	Gypsum ceiling	C1	30%	70%	18	8
5	GRC(Glass Reinforced Concrete) Board	C2	40%	60%	2	1
6	GRC Board WR (Water Resistant)	C3	40%	60%	3	1
7	Shadow Line (List Ceiling)	C4	0%	100%	5	4
8	ACP (Aluminum Composite Panel)	D1	30%	70%	46	25
9	Ceramic Floor 60x60 cm in Units	E1	30%	70%	28	15
10	Ceramic Floor 30x30 cm in Balcony & Toilet	E2	30%	70%	3	2
11	Ceramic Lobby Elevator	E3	30%	70%	3	2
12	Balcony Ceramic Plint & R. Panel	F1	0%	100%	4	3
13	Ceramic plinth HT (Homogenus Tile) 10/60 cm	F2	0%	100%	13	10
14	Ceramic Plint HT (Homogenus Tile) 10/30 cm (balcony unit)	F3	0%	100%	4	3
15	Wooden Door (Unit) P1	G1	20%	80%	40	25
16	PB1 Iron Door	G2	30%	70%	1	1
17	Iron Door Fire Door PB2A	G3	30%	70%	1	1
18	Door R Panel PB3	G4	30%	70%	1	1
19	GR1 Iron Grill Ventilation (emergency stairs & trash room)	G5	30%	70%	3	2
20	Iron Door PS1 Shaft	G6	30%	70%	12	7
21	PS2 Shaft Iron Door	G7	30%	70%	2	1
22	Aluminum P3 door (balcony)	G8	30%	70%	6	3
23	P2 UPVC door (toilet)	G9	30%	70%	6	3
24	Studio Unit Aluminum Window	G10	30%	70%	4	2
25	Aluminum Window 1800x1150 1 BR (unit)	G11	30%	70%	3	2
26	Aluminum Window 1,200x1,150 cm 1 BR (unit)	G12	30%	70%	1	1
27	J4 Window Aluminum Grill Jalus 800x1150 cm In Corridor	G13	30%	70%	1	1
28	J5 Aluminum windows 2,400x1,150 cm in Unit 1 BR	G14	30%	70%	1	1
29	Interior Wall Paint	H1	0%	100%	78	14
30	Facade Paint	H2	0%	100%	15	12
31	Exterior Paint	H3	0%	100%	12	9
32	Ceiling Paint	H4	0%	100%	20	16

Table 3 describes the weight of work and the remaining time for each job and explains the symbols for the type of work to be used for input in the POM-QM software.

Table 4: Activity Normal Costs

No	Work Activity	Symbol	Normal Costs (IDR)
1	Wall Waterproffing Coating	A1	190.220.000
2	Waterproffing Membrane	A2	340.570.000
3	Wall Ceramics	B1	999.540.000
4	Gypsum ceiling	C1	641.030.000
5	GRC (Glass Reinforced Concrete) Board	C2	69.350.000
6	GRC Board WR (Water Resistant)	C3	82.790.000
7	Shadow Line (List Ceiling)	C4	118.880.000
8	ACP (Aluminum Composite Panel)	D1	1.634.920.000
9	Ceramic Floor 60x60 cm in Units	E1	304.960.000
10	Ceramic Floor 30x30 cm in Balcony & Toilet	E2	265.770.000
11	Ceramic Lobby Elevator	E3	52.200.000
12	Balcony Ceramic Plint & R. Panel	F1	32.230.000
13	Ceramic plinth HT (Homogenus Tile) 10/60 cm	F2	3.760.000
14	Ceramic Plint HT (Homogenus Tile) 10/30 cm (balcony unit)	F3	1.920.180.000
15	Wooden Door (Unit) P1	G1	214.660.000
16	PB1 Iron Door	G2	318.900.000
17	Iron Door Fire Door PB2A	G3	39.160.000
18	Door R Panel PB3	G4	23.300.000
19	GR1 Iron Grill Ventilation (emergency stairs & trash room)	G5	651.940.000
20	Iron Door PS1 Shaft	G6	175.970.000
21	PS2 Shaft Iron Door	G7	1.374.680.000
22	Aluminum P3 door (balcony)	G8	898.470.000
23	P2 UPVC door (toilet)	G9	232.470.000
24	Studio Unit Aluminum Window	G10	338.720.000
25	Aluminum Window 1800x1150 1 BR (unit)	G11	48.520.000
26	Aluminum Window 1,200x1,150 cm 1 BR (unit)	G12	33.690.000
27	J4 Window Aluminum Grill Jalus 800x1150 cm In Corridor	G13	31.000.000
28	J5 Aluminum windows 2,400x1,150 cm in Unit 1 BR	G14	2.725.770.000
29	Interior Wall Paint	H1	523.250.000
30	Facade Paint	H2	162.020.000
31	Exterior Paint	H3	125.730.000
32	Ceiling Paint	H4	196.920.000
Totals:			14.771.570.000

Table 4. Describes the normal cost of activities. The financing for this project is also divided into two divisions, namely material costs, and wages. In this study, for material and wage costs, the author takes the basic unit price that already exists in the budget plan of the project being studied (Source: Taspen Project)

B. Develop a Crashing plan to get optimization.

Optimization is done by filling in data that will be optimized to be compared with the plan (baseline).

- Calculating work time optimization, with the addition of a target volume of work to be completed in 1 day.
- Calculating the number of workers required for the optimized work item.
- Calculating the additional costs incurred due to optimization.

Table 5: Activity Time Project

NO	SYMBOL	JOB DESCRIPTION	NORMAL TIME (Weeks)	Crashing TIME (Weeks)
1	A1	Wall Waterproffing Coating	12	6
2	A2	Waterproffing Membrane	7	4
3	B1	Wall Ceramics	25	16
4	C1	Gypsum ceiling	18	8
5	C2	GRC (Glass Reinforced Concrete) Board	2	1
6	C3	GRC WR (Water Resistant)	3	1
7	C4	Shadow Line (List Ceiling)	5	4
8	D1	ACP (Aluminum Composite Panel)	46	25
9	E1	Ceramic Floor 60x60 cm in Units	28	15

10	E2	Ceramic Floor 30x30 cm in Balcony & Toilet	3	2
11	E3	Ceramic Lobby Elevator	3	2
12	F1	Balcony Ceramic Plint & R. Panel	4	3
13	F2	Ceramic plinth HT 10/60 cm	13	10
14	F3	Ceramic Plint HT 10/30 cm (balcony unit)	4	3
15	G1	Wooden Door (Unit) P1	40	25
16	G2	PB1 Iron Door	1	1
17	G3	Iron Door Fire Door PB2A	1	1
18	G4	Door R Panel PB3	1	1
19	G5	GR1 Iron Grill Ventilation (emergency stairs & trash room)	3	2
20	G6	Iron Door PS1 Shaft	12	7
21	G7	PS2 Shaft Iron Door	2	1
22	G8	Aluminum P3 door (balcony)	6	3
23	G9	P2 UPVC door (toilet)	6	3
24	G10	Studio Unit Aluminum Window	4	2
25	G11	Aluminum Window 1,800x1,150 cm 1 BR (unit)	3	2
26	G12	Aluminum Window 1,200x1,150 cm 1 BR (unit)	1	1
27	G13	J4 Window Aluminum Grill Jalus 800x1,150 cm In Corridor	1	1
28	G14	J5 Aluminum windows 2,400x1,150 cm in Unit 1 BR	1	1
29	H1	Interior Wall Paint	78	14
30	H2	Facade Paint	15	12
31	H3	Exterior Paint	12	9
32	H4	Ceiling Paint	20	16

Table 5. describes the project acceleration time which is carried out by performing calculations based on the basic calculation of work volume from SNI (*Indonesian National Standart*).

Calculation example 1 (Wall Ceramic – B1):
Actual progress = 20%
Remaining progress = 80%
Initial volume = 6527.81 m^2
Residual volume = 5,222.25 m^2
Vol SNI = 14.286 m^2/day (1 worker/day)
= 14.286 x 7 days
= 100.002 m^2/day
Workers = 3 people
Normal time = 25 weeks
Deadline time = 16 weeks

- *Normal Productivity:*

$$\frac{\text{Remaining volume}}{\text{Normal duration}} = \frac{5{,}222.25}{25}$$

= 208.89 m^2/weeks

- *Crashing Productivity:*

$$\frac{\text{Productivity normal}}{\text{Koef. Crashing}} = \frac{208.89}{1.6}$$

= 334.224 m^2/weeks

- *Crash duration:*

$$\frac{\text{Remaining volume}}{\text{Crashing productivity}} = \frac{5{,}222.25}{334.224}$$

= 15.27 weeks = 16 weeks

Table 6: Activity Predecessor

Activity	Activity time (weeks)	Predecessor 1	Predecessor 2	Predecessor 3
A1	12			
A2	7	a1		
B1	25	a1		
C1	18	b1	a1	
C2	2	b1	c1	
C3	3	b1		
C4	5	a1	c3	
D1	46	a1		
E1	28	d1		
E2	3	b1		
E3	3	e2	c2	

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F1	4	e2		
F2	13	e1	c4	
F3	4	e2		
G1	40	f3	f1	
G2	1	e2		
G3	1	g2	g1	
G4	1	g3	e3	
G5	3	g4		
G6	12	g5		
G7	2	g6		
G8	6	e2	g7	
G9	6	b1		
G10	4	g9		
G11	3	g10		
G12	1	g11		
G13	1	g12		
G14	1	g13	g12	
H1	78	a1	a2	
H2	15	a1	g13	g7
H3	12	c4		
H4	20	c1		

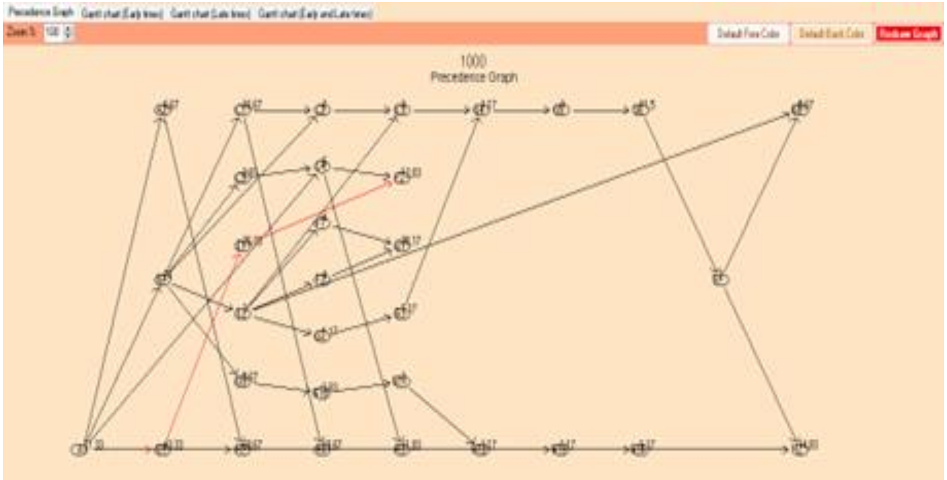

Fig. 2: Network Diagrams

Table 7: Forward and backward calculations and total float

Activity	**Activity time (weeks)**	**Early Start**	**Early Finish**	**Late Start**	**Late Finish**	**slack**
Project	**99**					
A1	12	0	12	0	12	0
A2	7	12	19	14	21	2
B1	25	12	37	18	43	6
C1	18	37	55	43	61	6
C2	2	55	57	61	63	6
C3	3	37	40	78	81	41
C4	5	40	45	81	86	41
D1	46	12	58	12	58	0
E1	28	58	86	58	86	0
E2	3	37	40	52	55	15
E3	3	57	60	63	66	6
F1	4	40	44	55	59	15
F2	13	86	99	86	99	0
F3	4	40	44	55	59	15
G1	40	44	84	59	99	15

G2	1	40	41	64	65	24
G3	1	41	42	65	66	24
G4	1	60	61	66	67	6
G5	3	61	64	67	70	6
G6	12	64	76	70	82	6
G7	2	76	78	82	84	6
G8	6	78	84	93	99	15
G9	6	37	43	69	75	32
G10	4	43	47	75	79	32
G11	3	47	50	79	82	32
G12	1	50	51	82	83	32
G13	1	51	52	83	84	32
G14	1	52	53	98	99	46
H1	78	19	97	21	99	2
H2	15	78	93	84	99	6
H3	12	45	57	87	99	42
H4	20	55	75	79	99	24

Under accelerated conditions, it can be seen in Table 7, that activities that are on a critical path with a slack value of zero (0) are activities:

- A1 = Waterproof Coating
- D1 = ACP (alumunium composite panel)
- E1 = Ceramic Floor 60x60 cm Units
- F2 = Ceramic Plint HT 10/60 cm

The required acceleration time is 99 weeks.

In the next condition relaxation is carried out, this changes the working time. There are 32 activities that can be accelerated as attached in Table 8 below:

Table 8: Calculation of forward and backward and total float (after relaxation)

Activity	Activity time weeks	Early Start	Early Finish	Late Start	Late Finish	slack
Project	**93,83**					
A1	11.33	0.00	11.33	0.00	11.33	0.00
A2	6,67	11.33	18.00	72,33	79.00	61.00
B1	24.00	11.33	35,33	24,67	48,67	13,33
C1	16,67	35,33	52.00	57.50	74,17	22,17
C2	2.00	35,33	37,33	80.00	82.00	44,67
C3	2.83	35,33	38,17	91.00	93,83	55,67
C4	5.00	11.33	16,33	88,83	93,83	77.50
D1	43,33	11.33	54,67	11.33	54,67	0.00
E1	26,33	54,67	81.00	54,67	81.00	0.00
E2	3.00	35,33	38,33	48,67	51,67	13,33
E3	3.00	38,33	41.33	90.83	93,83	52.50
F1	4.00	38,33	42,33	89,83	93,83	51.50
F2	12.83	81.00	93,83	81.00	93,83	0.00
F3	4.00	38,33	42,33	51,67	55,67	13,33
G1	38,17	42,33	80.50	55,67	93,83	13,33
G2	1.17	38,33	39.50	73,83	75.00	35.50
G3	1.17	39.50	40,67	75.00	76,17	35.50
G4	1.17	40,67	41.83	76,17	77,33	35.50
G5	3.00	41.83	44,83	77,33	80.33	35.50
G6	11.50	44,83	56,33	80.33	91.83	35.50
G7	2.00	56,33	58,33	91.83	93,83	35.50
G8	5,67	38,33	44.00	88,17	93,83	49,83
G9	5,67	35,33	41.00	77,83	83.50	42.50
G10	3.83	41.00	44,83	83.50	87.33	42.50
G11	3.00	44,83	47,83	87.33	90.33	42.50
G12	1.17	47,83	49.00	90.33	91.50	42.50

G13	1.17	49.00	50,17	91.50	92.67	42.50
G14	1.17	50,17	51,33	92.67	93,83	42.50
H1	68,67	11.33	80.00	25,17	93,83	13.83
H2	14.83	18.00	32,83	79.00	93,83	61.00
H3	11.83	37,33	49,17	82.00	93,83	44,67
H4	19.67	52.00	71,67	74,17	93,83	22,17

In table 8, the amount of time needed is **93.83** weeks.

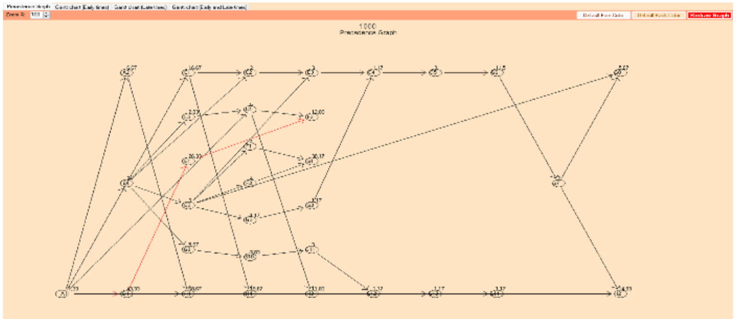

Fig. 3: Network Diagrams

C. Perform optimization analysis.

Table 9: Crashing schedule Critical Path Method

Activity	Normal time (Nt) weeks	Crash time (Ct) weeks	Normal Cost (IDR) (Nc)	Crash Cost (IDR) (Cc)	Δ Weeks	ΔCost (IDR)	ΔCost / Δ Weeks (IDR)
Project	**93,83**	**56.00**					
A1	11.33	6.00	190,220,000	211,140,000	5,33	20,920,000	3,486,700
A2	6,67	4.00	340,570,000	378,040,000	2.67	37,470,000	12,490,000
B1	24.00	16.00	999,540,000	1,109,490,000	8.00	109,950,000	12,216,700
C1	16,67	8.00	641,030,000	711,540,000	8.67	70,510,000	7,051,000
C2	2.00	1.00	69,350,000	76,980,000	1.00	7,630,000	7,630,000
C3	2.83	1.00	82,790,000	91,900,000	1.83	9,110,000	4,555,000
C4	5.00	4.00	118,880,000	131,960,000	1.00	13,080,000	13,080,000
D1	43,33	25.00	1,634,920,000	1,814,760,000	18.33	179,840,000	8,563,800
E1	26,33	15.00	304,960,000	338,510,000	11.33	33,550,000	2,580,800
E2	3.00	2.00	265,770,000	295,010,000	1.00	29,240,000	29,240,000
E3	3.00	2.00	52,200,000	57,940,000	1.00	5,740,000	5,740,000
F1	4.00	3.00	32,230,000	35,770,000	1.00	3,540,000	3,540,000
F2	12.83	10.00	3,760,000	4,170,000	2.83	410,000	136,700
F3	4.00	3.00	1,920,180,000	2,131,400,000	1.00	211,220,000	211,220,000
G1	38,17	25.00	214,660,000	238,270,000	13,17	23,610,000	1,574,000
G2	1.00	1.00	318,900,000	353,980,000	-	35,080,000	-
G3	1.00	1.00	39,160,000	43,460,000	-	4,300,000	-
G4	1.00	1.00	23,300,000	25,860,000	-	2,560,000	-
G5	3.00	2.00	651,940,000	723,660,000	1.00	71,720,000	71,720,000
G6	11.50	7.00	175,970,000	195,330,000	4.50	19,360,000	3,872,000
G7	2.00	1.00	1,374,680,000	1,525,900,000	1.00	151,220,000	151,220,000
G8	5,67	3.00	898,470,000	997,310,000	2.67	98,840,000	32,946,700
G9	5,67	3.00	232,470,000	258,050,000	2.67	25,580,000	8,526,700
G10	3.83	2.00	338,720,000	375,980,000	1.83	37,260,000	18,630,000
G11	3.00	2.00	48,520,000	53,860,000	1.00	5,340,000	5,340,000
G12	1.00	1.00	33,690,000	37,400,000	-	3,710,000	-
G13	1.00	1.00	31,000,000	34,410,000	-	3,410,000	-
G14	1.00	1.00	2,725,770,000	3,025,610,000	-	299,840,000	-
H1	68,67	14.00	523,250,000	580,800,000	54,67	57,550,000	899,200
H2	14.83	12.00	162,020,000	179,840,000	2.83	17,820,000	5,940,000
H3	11.83	9.00	125,730,000	139,570,000	2.83	13,840,000	4,613,300
H4	19.67	16.00	196,920,000	218,580,000	3.67	21,660,000	5,415,000
Totals			**14,771,570,000**			**1,624,910,000**	

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Table 10: List of Activities, optimistic time, most likely time, pessimistic time, standard deviation, and variance

Activity	Activity time	Early Start	Early Finish	Late Start	Late Finish	slack	Standard Deviations	Variances
Project	**93,83**						**5,33**	**28,36**
A1	11.33	-	11.33	-	11.33	-	1.33	1.78
A2	6,67	11.33	18.00	18.50	25,17	7,17	0.67	0.44
B1	24.00	11.33	35,33	15,67	39,67	4,33	2.00	4.00
C1	16,67	35,33	52.00	39,67	56,33	4,33	2.00	4.00
C2	2.00	52.00	54.00	56,33	58,33	4,33	0.33	0.11
C3	2.83	35,33	38,17	73,17	76.00	37,83	0.50	0.25
C4	5.00	38,17	43,17	76.00	81.00	37,83	0.33	0.11
D1	43,33	11.33	54,67	11.33	54,67	-	4,33	18.78
E1	26,33	54,67	81.00	54,67	81.00	-	2.67	7,11
E2	3.00	35,33	38,33	48,67	51,67	13,33	0.33	0.11
E3	3.00	54.00	57.00	58,33	61,33	4,33	0.33	0.11
F1	4.00	38,33	42,33	51,67	55,67	13,33	0.33	0.11
F2	12.83	81.00	93,83	81.00	93,83	-	0.83	0.69
F3	4.00	38,33	42,33	51,67	55,67	13,33	0.33	0.11
G1	38,17	42,33	80.50	55,67	93,83	13,33	3,17	10.03
G2	1.17	38,33	39.50	59.00	60,17	20,67	0.17	0.03
G3	1.17	39.50	40,67	60,17	61,33	20,67	0.17	0.03
G4	1.17	57.00	58,17	61,33	62.50	4,33	0.17	0.03
G5	3.00	58,17	61,17	62.50	65.50	4,33	0.33	0.11
G6	11.50	61,17	72,67	65.50	77.00	4,33	1.17	1.36
G7	2.00	72,67	74,67	77.00	79.00	4,33	0.33	0.11
G8	5,67	74,67	80.33	88,17	93,83	13.50	0.67	0.44
G9	5,67	35,33	41.00	64,17	69,83	28,83	0.67	0.44
G10	3.83	41.00	44,83	69,83	73,67	28,83	0.50	0.25
G11	3.00	44,83	47,83	73,67	76,67	28,83	0.33	0.11
G12	1.17	47,83	49.00	76,67	77,83	28,83	0.17	0.03
G13	1.17	49.00	50,17	77,83	79.00	28,83	0.17	0.03
G14	1.17	50,17	51,33	92.67	93,83	42.50	0.17	0.03
H1	68,67	18.00	86,67	25,17	93,83	7,17	12.00	144.00
H2	14.83	74,67	89.50	79.00	93,83	4,33	0.83	0.69
H3	11.83	43,17	55.00	82.00	93,83	38,83	0.83	0.69
H4	19.67	52.00	71,67	74,17	93,83	22,17	1.00	1.00

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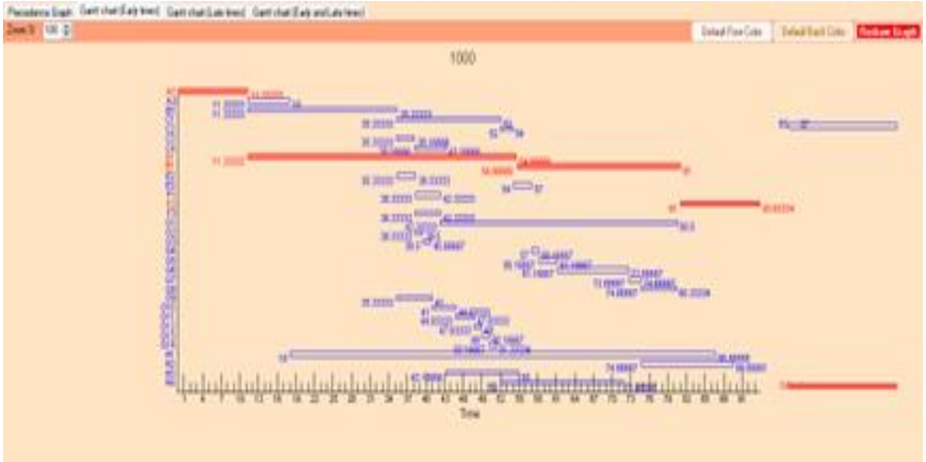

Fig. 4: Gantt Chart Early times

The activity in Figure 4, which is located on the red line, is the critical path. So, by using PERT it can be determined the sequence of work and the attachment relationship between work activities that cannot be separated. This attachment can be seen if certain work has not been done, then the next work cannot be done.

Table 11: Activity Time Computations

	Optimistic time	Most likely time	Pessimistic time	Activity time	Standard Deviation	Variances
A1	6.00	12.00	14.00	11.33	1.33	1.78
A2	4.00	7.00	8.00	6,67	0.67	0.44
B1	16.00	25.00	28.00	24.00	2.00	4.00
C1	8.00	18.00	20.00	16,67	2.00	4.00
C2	1.00	2.00	3.00	2.00	0.33	0.11
C3	1.00	3.00	4.00	2.83	0.50	0.25
C4	4.00	5.00	6.00	5.00	0.33	0.11
D1	25.00	46.00	51.00	43,33	4,33	18.78
E1	15.00	28.00	31.00	26,33	2.67	7,11
E2	2.00	3.00	4.00	3.00	0.33	0.11
E3	2.00	3.00	4.00	3.00	0.33	0.11
F1	3.00	4.00	5.00	4.00	0.33	0.11
F2	10.00	13.00	15.00	12.83	0.83	0.69
F3	3.00	4.00	5.00	4.00	0.33	0.11
G1	25.00	40.00	44.00	38,17	3,17	10.03
G2	1.00	1.00	2.00	1.17	0.17	0.03
G3	1.00	1.00	2.00	1.17	0.17	0.03
G4	1.00	1.00	2.00	1.17	0.17	0.03
G5	2.00	3.00	4.00	3.00	0.33	0.11
G6	7.00	12.00	14.00	11.50	1.17	1.36
G7	1.00	2.00	3.00	2.00	0.33	0.11
G8	3.00	6.00	7.00	5,67	0.67	0.44
G9	3.00	6.00	7.00	5,67	0.67	0.44
G10	2.00	4.00	5.00	3.83	0.50	0.25
G11	2.00	3.00	4.00	3.00	0.33	0.11
G12	1.00	1.00	2.00	1.17	0.17	0.03
G13	1.00	1.00	2.00	1.17	0.17	0.03
G14	1.00	1.00	2.00	1.17	0.17	0.03
H1	14.00	78.00	86.00	68,67	12.00	144.00
H2	12.00	15.00	17.00	14.83	0.83	0.69
H3	9.00	12.00	14.00	11.83	0.83	0.69
H4	16.00	20.00	22.00	19.67	1.00	1.00
Project results						
Sum of crit act var						**28,36**
Sum of total var						**197,12**
Square root of total					**5,33**	

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The overall variance value in table 11is the total variance of all activities, namely **197.12.** The project standard deviation value is calculated from the root of the total variance, which is **14.0399.**

$$=\sqrt{197.12} = 14.0399$$

The Z value of the project being studied can be calculated using the formula:

$$Z=\frac{\mathbf{T(d)\text{-}TE}}{\mathbf{S}}$$

Information:

Z	= Probability (chance)
T(d)	= Deadline
TE	= Expected Completion Time
S	= Standard Deviation Total Variance

$$Z=\frac{99\text{-}56}{14.0399}=\frac{43}{14.0399}=3.036$$

Table 13: Normal Distribution (Z)

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.5	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
-0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998

The Z value of this project is 3.036 , based on the normal distribution table, the probability of doing this project in **56 weeks** is: **0.998** .

0.998 x 100% = 99.8%

From the Z value, the project under study can be done in 56 weeks with a 99.8 % chance.

V. CONCLUSION

- Optimization of the time and cost of construction projects required:
- ✓ Based on the results of the rescheduled analysis, the project completion time is expected to be **99 weeks.** Rescheduling with the PERT method, obtained the optimal duration, namely days from the 5th to 11th floor Architectural work and the roof top was completed.
- ✓ Based on the results of the analysis, the total cost of completing the architectural work from the 5th floor to the 11th floor is IDR **16,392,493,000.** With the addition of a settlement fee of IDR**1,624,910,000.** From the normal cost of IDR**14,771,583,000.**
- System Crashing done using the POM-QM For Windows Application:
- ✓ In terms of time, the resulting time acceleration is **56 weeks** faster than the normal time, which is 99 weeks.
- Based on rescheduling analysiswith the PERT method, the optimal probability for the project to run according to the target duration of 56 weeks is **99.8%,** with a value of Z = 3.063.

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