

ANALYSIS OF PROJECT DELAY USING THE CRITICAL PATH METHOD (CPM): A CASE STUDY ON THE CONSTRUCTION PROJECT OF THE OPD OFFICE BUILDING IN PASURUAN

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Abstract

In construction project control, the main factors of concern are quality, time and cost control. So it is necessary to use one method in the implementation of control. This study aims to analyze the time and cost of the Raci OPD Office Building Construction project. The benefit of this research is to anticipate potential delays that occur in the project. The problem limitation is focused on work that has not been completed in the remaining time of the contract period. To analyze time and cost, this research uses Critical Path Method (CPM) and Time-Cost Trade-Off (TCTO) which begins with determining the work network and critical path. TCTO analysis is carried out by shortening the duration of work by adding 3 hours of overtime and calculating the Crash Slope of each job on the critical path. Rescheduling is done by accelerating the work that has the lowest cost. The results showed that the most effective rescheduling was carried out on the Lt.3 Installation and Plastering work with the acquisition of an acceleration duration of 8 days. And the total cost required for this acceleration is Rp. 29,441,424, - or Rp. 1,226,726, - per day for 24 days.

Keywords: CPM, TCTO, Crashing Program

1. INTRODUCTION

The development of the construction sector in Indonesia is currently growing to meet the needs of the community which is expected to have a positive impact on the economic development of the State of Indonesia (Undang-Undang et al., 2003).

A construction project is a series of activities carried out to build a building within a specified time period. The most important goal for contractors as service providers and service users is that construction projects can be completed on time (Soeharto, 1999), at the right cost and at the right quality (Yaqin et al., 2023). In the reality of implementing construction projects, delays in work completion are often encountered. Project delay is the completion of a project that exceeds the time limit specified in the contract. This obstacle causes losses both from the contractor as the executor and the assignor. (Heizer & Render, 2015) Therefore, management is needed to control time, quality and cost.

(Mantel et al., 2001) Project management is the application of knowledges, skills, tools and techniques in project activities to meet project needs (PMBOK 2017).

Project management is carried out through the application and integration of the stages of the project management process, namely initiating, planning, executing, monitoring, and controlling and finally closing the entire project process (Clive et al., 1993). In its implementation, every project is always limited by constraints - constraints that affect each other and are commonly referred to as the project constraint triangle, namely: scope of work (scope), time and cost (Abadiyah et al., 2019). Where the balance of the three constraints will determine the quality of a project. Changes in one or more of these factors will affect at least one other factor. (Institute, 2017)

Control is a systematic effort to determine standards in accordance with planning objectives, design information systems, compare implementation with standards, analyze possible deviations between implementation and standards and take the necessary corrective actions so that resources are used effectively and efficiently in order to achieve goals. (Soeharto, 1999)

The OPD Office Building Construction Project in the Raci Office Complex, started on May 26, 2023 with an implementation duration of 210 calendar days with an implementation budget of Rp. 18,335,039,000.00. The OPD Office Building being built is planned to consist of 3 (three floors). The implementation of this project includes:

1. Structure Work

Structural work includes: foundation work, pile cap, sloof, columns, beams and floor plates. The foundation structure used in this work uses 40 x 40 piles with K500 concrete quality, as many as 207 points.

2. Architectural Works

Architectural work carried out includes: brick wall installation work, frames, ceilings, painting, floor and wall coverings.

3. Mechanical, Electrical and Plumbing (MEP) Works

MEP work includes electrical work, air conditioning, elevator work, telecommunications, sanitation and ducts.

Based on observations during implementation, which until this article was compiled entered week 19, the progress of work in the field still shows a positive deviation value. However, if analyzed more deeply, the deviation value of progress until week 19 is inversely proportional to the average productivity each week.

Based on Primary Data from the Supervisory Consultant, (2023) shows that the value of work deviation continues to decline. In week 16 there was still a deviation of 11.572% but continued to decline until it remained around 4.051%. And when viewed based on weekly productivity, it also continues to decline.

Primary Data from Supervisory Consultant, (2023). From the S Curve, the blue line is the implementation plan, while the red line is the realization. The area between the red and blue lines is the progress deviation value. The more to the right, the narrower the deviation area. So if not anticipated, it will cause a minus deviation, which means there is a delay in implementation.

In addition, if calculated from the remaining time available, there is an indication that there will be a delay. Because if the calculation of the remaining time is less than 50%, it still has to catch up with the progress of around 60%. So it is necessary to accelerate and anticipate efforts so that delays do not occur.

This research was conducted as an effort to prevent delays in implementation. So it is expected to be applied so that it can be carried out on time. One of the methods used is the CPM (Critical Path Method) method (Danniyanti, 2010).

In the scheduling procedure with the CPM (Critical Path Method) (Danang Prihandoko et al., 2022) method or critical path method it is assumed that the duration of a component of project activities is considered to be known for certain (Lilyana, 2020). This CPM (Sa'adah & Rijanto, 2021) method aims to plan and control a large number of activities that have complex dependency relationships in engineering design, construction and maintenance problems (Marpaung et al., n.d.).

The research begins by breaking down the work into several work components that will be organized into a network (network planning). This network serves to determine the relationship between each work component and its predecessor. From the work network, it will be known which components do not have free time and must be done on time. Then each component is arranged as a critical path.

2. RESEARCH METHODS

The subject of the research is in the form of data collected from various sources related to the Construction of the OPD Office Building in the Raci Office Complex. The data that will be used as research subjects are time schedule data and RAB from the Implementing Contractor and work progress report data from the Supervisory Consultant in the field. The research location is in the Raci Office Complex, Pasuruan Regency. The OPD Office Building of the Raci Office Complex under construction consists of 3 floors which function as office buildings and are owned by the Pasuruan Regency Government. The research instruments used are methods of accelerating work including Critical Path Method (CPM)(JAYA, n.d.) and Time-Cost Trade-Off (TCTO)(Rosyid et al., 2020). Data processing using Microsoft Excel and Microsoft Project 2017 applications. The data used in this study are primary data and secondary data. Primary data is data on the implementation of the OPD Office Building Construction in the Raci Office Complex, which is collected from the Supervisory Consultant. While secondary data is obtained from literature studies which are used as study materials during the research process(Rakasyiwi et al., 2022). Data analysis techniques in this research are Critical Path Method and Time Cost Trade Off(Budianto & Husin, 2021).

3. RESULTS AND DISCUSSION

The work progress data received as the object of research is in the form of a time schedule in the form of an s-curve. The data to be processed in this study is progress data for week 20. The following is the time schedule data for week 20:

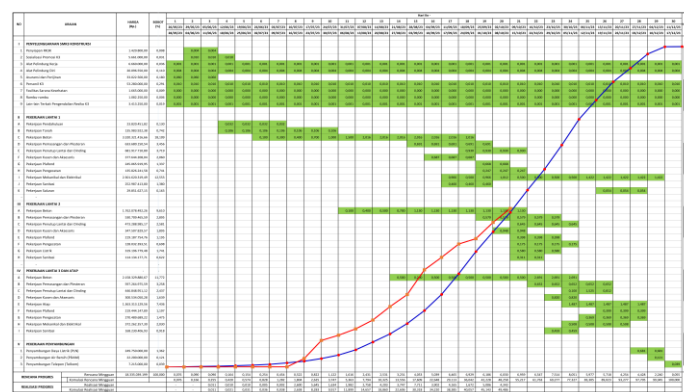


Figure 1. S-Curve of Work Progress Report
(Source: Supervisory Consultant, 2023)

From the data collected, a simple analysis has been carried out by comparing the remaining duration with the speed of work implementation to obtain the following initial hypothesis(Manurung, 2018):

Table 1. Implementation Achievements of the Last 5 (five) Weeks

No	Rencana	Realisasi	Deviasi	Prosentase
M-16	5,039	3,902	-1,137	77,44%
M-17	6,465	4,165	-2,3	64,42%
M-18	6,929	1,672	-5,257	24,13%
M-19	6,186	5,086	-1,1	82,22%
M-20	6,03	4,343	-1,687	72,02%
Rata-rata		3,8336	-2,2962	64,05%

The remaining work that must still be completed by the Construction Executor is around 50.6%. Data on the remaining work and the duration required in detail can be seen in the table below:

Table 2. List of remaining work to be completed

No	Aktifitas	Biaya (Rp)	Kode
A. Lantai 2			
1	Pekerjaan Beton	1.762.078.492,26	A
2	Pekerjaan Pemasangan dan Plesteran	530.709.465,59	B
3	Pekerjaan Penutup Lantai dan Dinding	473.288.985,17	C
4	Pekerjaan Kusen dan Aksesoris	347.507.829,57	D
5	Pekerjaan Plafond	219.187.754,76	E
6	Pekerjaan Pengecatan	128.032.393,51	F
7	Pekerjaan Listrik	319.196.779,48	G
8	Pekerjaan Sanitasi	114.134.177,71	H
	Jumlah Biaya Lantai 2	3.894.135.878,05	
B. Lantai 3			
9	I. LT.3 Pekerjaan Beton	2.158.329.880,67	I
10	J. LT.3 Pekerjaan Pemasangan dan Plesteran	597.264.975,59	J
11	K. LT.3 Pekerjaan Penutup Lantai dan Dinding	446.848.951,12	K
12	L. LT.3 Pekerjaan Kusen dan Aksesoris	300.534.050,28	L
13	M. LT.3 Pekerjaan Atap	1.363.313.129,56	M
14	N. LT.3 Pekerjaan Plafond	219.444.147,89	N
15	O. LT.3 Pekerjaan Pengecatan	270.489.689,22	O
16	P. LT.3 Pekerjaan Mekanikal dan Elektrikal	372.262.357,30	P
17	Q. LT.3 Pekerjaan Sanitasi	168.230.406,93	Q
	Jumlah Biaya Lantai 3	5.896.717.588,56	
	Total Biaya Pekerjaan Lantai 2 dan 3	9.790.853.466,61	

(Source: Project Data, 2023)

Determination of the implementation time is taken from the work plan data of the implementing contractor.

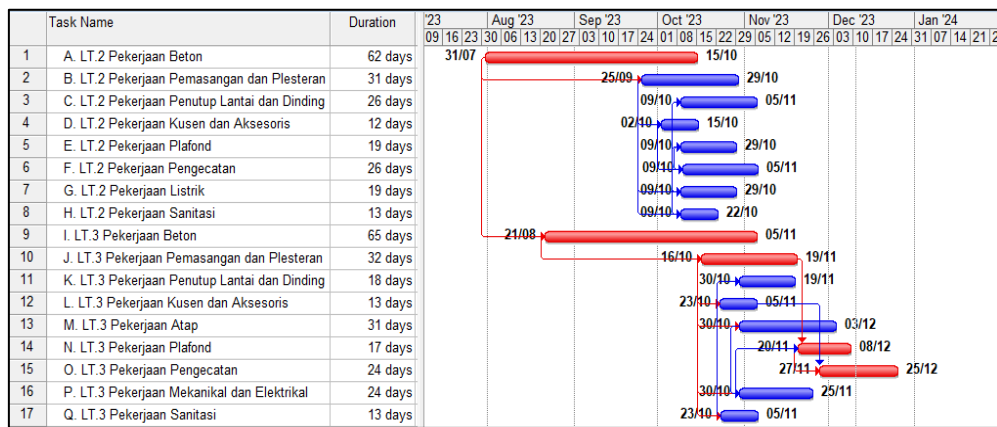


Figure 2. Scheduling with Ms. Project
(Source: Data Processing, 2023)

From the above scheduling, it can be seen that the overall work will end on December 25, 2023. Contractually, the work must be handed over no later than December 21, 2023. So that acceleration efforts need to be made.

To carry out the acceleration, first determine the critical trajectory of this work. Critical activities are obtained from the table on Ms.Project as follows:

Table 3. Critical activities in the remaining work

Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1. A. LT.2 Pekerjaan Beton	Mon 31/07/23	Sun 15/10/23	Mon 31/07/23	Sun 15/10/23	0 days	0 days
2. B. LT.2 Pekerjaan Pemasangan dan Plesteran	Mon 25/09/23	Sun 29/10/23	Fri 17/11/23	Sat 23/12/23	5,63 days	48 days
3. C. LT.2 Pekerjaan Penutup Lantai dan Dinding	Mon 09/10/23	Sun 05/11/23	Fri 24/11/23	Mon 25/12/23	42,75 days	42,75 days
4. D. LT.2 Pekerjaan Kusen dan Aksesoris	Mon 02/10/23	Sun 15/10/23	Fri 17/11/23	Fri 01/12/23	0 days	42,38 days
5. E. LT.2 Pekerjaan Plafond	Mon 09/10/23	Sun 29/10/23	Fri 24/11/23	Sat 16/12/23	0,38 days	42,75 days
6. F. LT.2 Pekerjaan Pengecatan	Mon 09/10/23	Sun 05/11/23	Fri 24/11/23	Mon 25/12/23	42,38 days	42,38 days
7. G. LT.2 Pekerjaan Listrik	Mon 09/10/23	Sun 29/10/23	Fri 24/11/23	Sat 16/12/23	0 days	42,75 days
8. H. LT.2 Pekerjaan Sanitasi	Mon 09/10/23	Sun 22/10/23	Fri 24/11/23	Fri 08/12/23	0 days	42,75 days
9. I. LT.3 Pekerjaan Beton	Mon 21/08/23	Sun 05/11/23	Mon 21/08/23	Sun 05/11/23	0 days	0 days
10. J. LT.3 Pekerjaan Pemasangan dan Plesteran	Mon 16/10/23	Sun 19/11/23	Mon 16/10/23	Sun 19/11/23	0 days	0 days
11. K. LT.3 Pekerjaan Penutup Lantai dan Dinding	Mon 30/10/23	Sun 19/11/23	Sun 03/12/23	Mon 25/12/23	30,88 days	30,88 days
12. L. LT.3 Pekerjaan Kusen dan Aksesoris	Mon 23/10/23	Sun 05/11/23	Sat 11/11/23	Mon 27/11/23	18,5 days	18,5 days
13. M. LT.3 Pekerjaan Atap	Mon 30/10/23	Sun 03/12/23	Fri 10/11/23	Sat 16/12/23	0 days	10,88 days
14. N. LT.3 Pekerjaan Plafond	Mon 20/11/23	Fri 08/12/23	Mon 20/11/23	Fri 08/12/23	0 days	0 days
15. O. LT.3 Pekerjaan Pengecatan	Mon 27/11/23	Mon 25/12/23	Mon 27/11/23	Mon 25/12/23	0 days	0 days
16. P. LT.3 Pekerjaan Mekanikal dan Elektrikal	Mon 30/10/23	Sat 25/11/23	Fri 10/11/23	Thu 07/12/23	10,88 days	10,88 days
17. Q. LT.3 Pekerjaan Sanitasi	Mon 23/10/23	Sun 05/11/23	Sun 03/12/23	Tue 19/12/23	6,5 days	37,38 days

(Source: Ms. Project, 2023)

3.1. Calculation of Normal and Accelerated Daily Productivity

Normal daily productivity is daily productivity at normal duration in accordance with the initial scheduling. While accelerated productivity is daily productivity after acceleration. acceleration can be calculated by adding overtime working hours of 3 hours per day on all work on the critical path. If a breakdown of each job is carried out, the following work details and labor costs will be obtained:

Table 4. Breakdown of Work and Labor Cost on Critical Work

No	Pekerjaan	Vol.	Sat	Biaya Personil	Overhead 2,5%	Jumlah Biaya Personil
				(Rp)	(Rp)	(Rp)
1	LT. 2 PEKERJAAN BETON					
	Pekerjaan Beton	299,68	m3	114.275.476	2.856.887	117.132.363
	Pembesian Ulir	53.168,15	Kg	119.335.913	2.983.398	122.319.311
	Bekisting	1.922,10	m2	300.337.736	7.508.443	307.846.179
		JUMLAH		533.949.124	13.348.728	547.297.852
2	LT. 3 PEKERJAAN BETON					
	Pekerjaan Beton	330	m3	125.837.250	3.145.931	128.983.181
	Pembesian Ulir	67.889,32	Kg	152.377.579	3.809.439	156.187.018
	Bekisting	2.436,34	m2	380.690.307	9.517.258	390.207.565
		JUMLAH		658.905.135	16.472.628	675.377.763
3	LT. 3 PEKERJAAN PEMASANGAN DINDING DAN PLESTERAN					
	Pas. Dinding 1/2 Bata Merah 1:5	940,68	m2	59.027.670	1.475.692	60.503.362
	Pemasangan Metal Stud	275,61	m2	22.036.398	550.910	22.587.308
	Pemasangan Gypsum Board Partisi t = 12 mm	551,21	m2	13.049.897	326.247	13.376.144
	Plesteran Halus 1:5 + Acian	1.881,36	m2	133.623.594	3.340.590	136.964.184
	Benangan	958,31	m'	50.311.275	1.257.782	51.569.057
	Profil List GRC	271,6	m'	5.206.572	130.164	5.336.736
		JUMLAH		283.255.405	7.081.385	290.336.790
4	LT. 3 PEKERJAAN PLAFON					
	Pek. Plafond dan Gypsum	740,14	m2	82.825.367	2.070.634	84.896.001
	Pek. List Gypsum	622,11	m1	11.925.849	298.146	12.223.995
		JUMLAH		94.751.215	2.368.780	97.119.995
5	LT.3 PEKERJAAN PENGECATAN					
	Pek. Pengecatan dinding, Plafon dan Gypsum	2.232,03	m2	30.861.163	771.529	31.632.692
	Pek. Pengecatan dinding luar baru Water Shield	475,13	m2	6.531.375	163.284	6.694.659
	Pek. Pengecatan Waterproofing	181,69	m2	2.078.352	51.959	2.130.311
	Pek. Pengecatan Besi	1.104,77	m2	98.020.718	2.450.518	100.471.236
	Pek. Pengecatan Kalsiplank	55,5	m2	720.390	18.010	738.400
		JUMLAH		138.211.998	3.455.300	141.667.298

(Source: Data Processing, 2023)

With the same calculation method, the results for all sub-jobs are as follows:

Table 5. Normal and Accelerated Daily Productivity on Critical Work

No	Pekerjaan	Volume	Sat	Prod. Normal Per Hari	Prod. Percepatan Per Hari
1	LT. 2 PEKERJAAN BETON				
	Pekerjaan Beton	299,68	m3	4,83	6,49
	Pembesian Ulir	53.168,15	Kg	857,55	1.151,57

No	Pekerjaan	Volume	Sat	Prod. Normal Per Hari	Prod. Percepatan Per Hari
	Bekisting	1.922,10	m ²	31,00	41,63
2	LT. 3 PEKERJAAN BETON				
	Pekerjaan Beton	330,00	m ³	5,08	6,82
	Pembesian Ulir	67.889,32	Kg	1.044,45	1.402,55
	Bekisting	2.436,34	m ²	37,48	50,33
3	LT. 3 PEKERJAAN PEMASANGAN DINDING DAN PLESTERAN				
	Pas. Dinding 1/2 Bata Merah 1:5	940,68	m ²	29,40	39,47
	Pemasangan Metal Stud 3.4x7.6 Partisi	275,61	m ²	8,61	11,57
	Pemasangan Gypsum Board Partisi t = 12 mm	551,21	m ²	17,23	23,13
	Plesteran Halus 1:5 + Acian	1.881,36	m ²	58,79	78,95
	Benangan	958,31	m'	29,95	40,21
	Profil List GRC	271,60	m'	8,49	11,40
4	LT. 3 PEKERJAAN PLAFON				
	Pek. Plafond Rangka Hollow dan Gypsum	740,14	m ²	43,54	58,46
	Pek. List Gypsum	622,11	m'	36,59	49,14
5	LT.3 PEKERJAAN PENGECATAN				
	Pek. Pengecatan dinding, Plafon dan Gypsum	2.232,03	m ²	93,00	124,89
	Pek. Pengecatan dinding luar baru Water Shield	475,13	m ²	19,80	26,58
	Pek. Pengecatan Waterproofing	181,69	m ²	7,57	10,17
	Pek. Pengecatan Besi	1.104,77	m ²	46,03	61,81
	Pek. Pengecatan Kalsiplank	55,50	m ²	2,31	3,11

(Source: Data Processing, 2023)

3.2. Calculation of Crash Duration, Crash Cost and Crash Slope

a. Crash Duration

Crash Duration is the duration of acceleration obtained by adding 3 hours of overtime every day (Oetomo et al., 2017). The acceleration duration can be calculated in the following way:

With the same calculation, the results are obtained as in the following table:

Table 6. Duration under Normal and Accelerated Conditions

No	Pekerjaan	Durasi Normal (Hari)	Durasi Percepatan (Hari)
1	Lt. 2 Pek. Beton	62	47
2	Lt. 3 Pek. Beton	65	49
3	Lt. 3 Pek. Pemasangan dan Plesteran	32	24
4	Lt. 3 Pek. Plafond	17	13
5	Lt. 3 Pek. Pengecatan	24	18

(Source: Data Processing, 2023)

b. Crash Cost dan Crash Slope

From the data on changes in work duration after the Crashing Program, the costs required to implement the acceleration can be calculated. The costs incurred during the Crashing Program consist of direct costs and indirect costs. Direct costs are costs incurred for personnel wages during acceleration. While indirect costs are additional costs of work carrying capacity that must be incurred during acceleration.

With the calculation, a recap of the results of the Crash Cost calculation is obtained as follows:

Table 7. Crash Cost and Crash Slope Calculation Results

No	Pekerjaan	Normal		Percepatan		Crash Slope (Rp/hari)
		Durasi (Hari)	Biaya Personil (Rp.)	Durasi (Hari)	Biaya Personil (Rp.)	
1	Lt. 2 Pek. Beton	62	547.297.852	47	740.869.789	12.904.796
2	Lt. 3 Pek. Beton	65	675.377.763	49	909.162.374	14.611.538
3	Lt. 3 Pek. Pemasangan dan Plesteran	32	290.336.790	24	319.778.215	3.680.178
4	Lt. 3 Pek. Plafon	17	97.119.995	13	132.621.843	27.148.472
5	Lt. 3 Pek. Pengecatan	24	141.667.298	18	189.732.988	8.010.948

(Source: Data Processing, 2023)

From the table above, it is obtained that the lowest Crash Slope is in the work of Lt.3 Installation and Plastering Work at Rp. 3,680,178, - / day with the result of an accelerated duration of 8 days. As for the total cost of implementation of the acceleration can be seen in the table below:

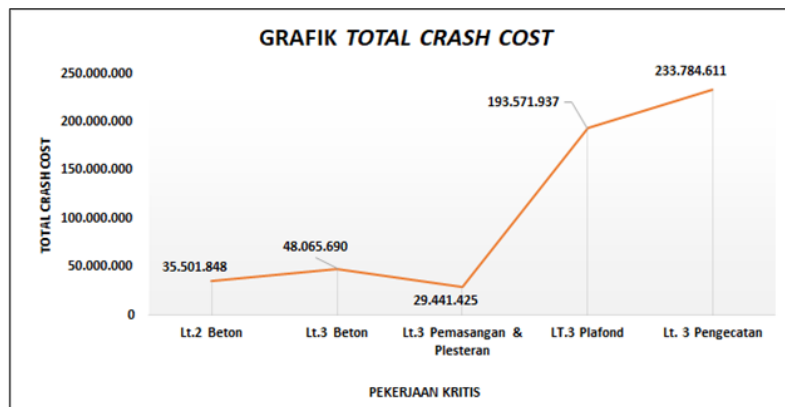


Figure 3. Crash Slope Graph On Critical Work

(Source: Data Processing, 2023)

The graph above shows that acceleration by increasing working hours (overtime) by 3 hours, the lowest implementation cost is on the 3rd floor work of Installation and Plastering Work at a cost of Rp. 29,441,425. The cost mentioned above is the cost incurred for additional working hours only including the accompanying indirect costs (excluding materials). Material costs are ignored because they are fixed according to initial needs.

3.3. Rescheduling of Remaining Work

Based on the analysis obtained above, rescheduling is carried out by accelerating specifically on the work of Lt. 3 Wall Installation and Plastering. The results of scheduling are done with Ms.Project with the results as shown below:

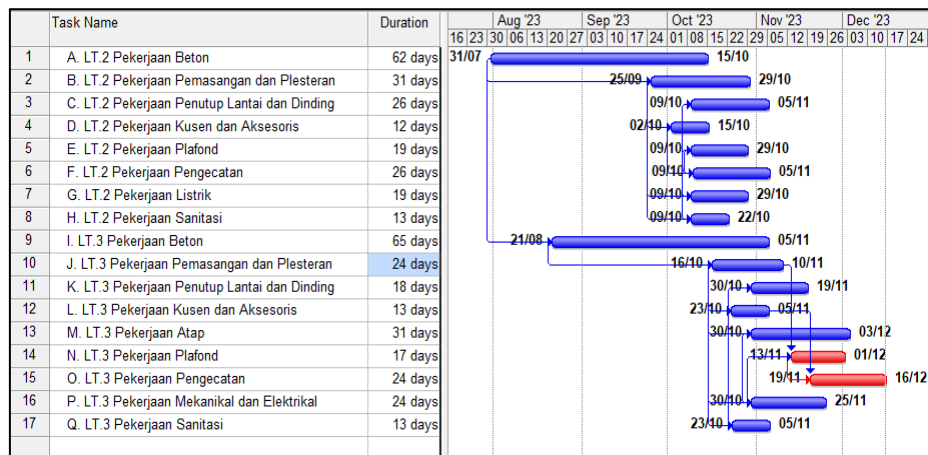


Figure 4. Rescheduling Results with Ms.Project
(Source: Ms.Project 2017, Data Processing 2023)

In the diagram above, it can be seen that the end of the work is on December 16, 2023, and is still within the original contract duration of the work. So if this schedule can be met, then this project is not late.

The results of this schedule change can be applied in the work network diagram as follows (Saputra et al., 2021):

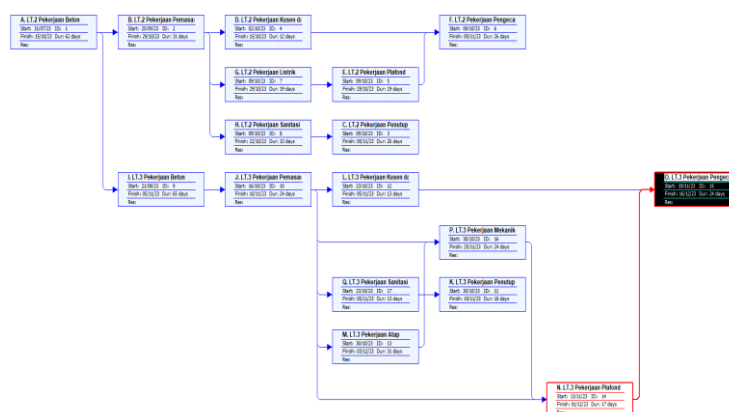


Figure 5. Network Planning Ms. Project According To Rescheduling
(Source: Ms.Project 2017, Data Processing 2023)

From the picture above, it can be seen that critical activities remain on the ceiling and painting work on the 3rd floor. So that both jobs must be completed on time. Based on the calculation and rescheduling with Ms. Project above, it can be concluded that crashing the 3rd floor painting work can avoid delays.

4. CONCLUSIONS and SUGGESTIONS

4.1 CONCLUSIONS

Based on the results of this study, several things can be concluded. First, the addition of overtime hours of 3 hours per day in all types of work has a positive impact on the 3rd Floor Installation & Plastering work, which results in the lowest Cost Slope. In addition, the addition of overtime hours also succeeded in accelerating the duration of the work by 8 days ahead of the original schedule. However, it should be noted that this result was also accompanied by an additional cost of Rp. 29,441,425 as a consequence of implementing the Crashing Program on the work.

4.2 SUGGESTIONS

The researcher's recommendations on these findings include several aspects. First, acceleration through the crashing program method can be considered as an alternative solution to overcome project delays. The second recommendation is to develop this research further, as well as compare it with other methods such as the PERT method to gain a deeper understanding of its effectiveness. In addition, the author also suggests that the additional costs arising from the application of this method can be further optimized, given the remaining time available from the contract period of the project. Thus, this research provides the potential to continue to be improved and optimized for better results.

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