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STUDY OF COST AND TIME ANALYSIS USING THE TIME COST TRADE OFF (TCTO) METHOD IN THE CONSTRUCTION PROJECT OF THE OFFICE BUILDING OF A GOVERMENT AGENCY (OPD) IN PASURUAN

Didik Purnomo[1*], Wateno Oetomo[2], Risma Marleno[3]
[1-3]Master of Civil Engineering Study Program, Faculty of Engineering,
Universitas 17 Agustus 1945 Surabaya
E-mail: [1)] d2k.purnomo@gmail.com

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 its 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

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, at the right cost and at the right quality. In the reality of implementing construction projects often face delays in the completion of work. 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. Therefore, management is needed to control time, quality and cost. Project management is the application of knowledges, skills, tools and techniques in project activities to meet project needs.(PMBOK 2017)(Institute, 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(Mantel et al., 2001). 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. 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. (PMBOK 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).

Controlling a large project involves keeping a close eye on resources, costs, quality, and budget. Controlling also means using feedback loops to revise or change project plans and shifting or reorganizing resources to meet time and cost requirements.

Control measures can be taken in terms of cost and time. Time control can be done by looking at the performance of project implementation that has taken place(Dannyanti, 2010). The implementation of a project can be delayed, accelerated, or on time according to the project plan scheduling depending on the conditions of each project.

One of the methods used is the critical path method (CPM) which is done by compiling a work network. Such a control process can also be carried out on the OPD Office Building Construction Project at the Raci Office Complex, Pasuruan Regency(Sa'adah & Rijanto, 2021). 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 the following works:

1. Structure Work
   The 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 Work
   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 ductwork.

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. The following is a table of observations made in the last 3 weeks. The work deviation value continues to decrease. In week 16 there was still a deviation of 11.572% but it continued to decline until it remained around 4.051%. And when viewed based on weekly productivity, it also continues to decline as shown in the S Curve.

Based on Primary Data from Supervision 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 are indications that there will be delays. 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 to avoid delays.

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(Lilyana, 2020).

In the scheduling procedure with the CPM (Critical Path Method) method or critical path method, it is assumed that the duration of a component of project activities is considered to be known with certainty (Danang Prihandoko et al., 2022). (Saputra et al., 2021)This CPM method aims to plan and control a large number of activities that have complex dependency relationships in engineering design, construction and maintenance problems (JAYA, 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. (Rosyid et al., 2020)The research instruments used are methods of accelerating work including Critical Path Method (CPM) and Time-Cost Trade-Off (TCTO). (Rakasyiwi et al., 2022)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 that are used as study materials during the research process . Data analysis techniques in this study are Critical Path Method and Time Cost Trade Off(Budianto & Husin, 2021).

3. RESULTS AND DISCUSSION

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:

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

No.	Plan	Realization	Deviation	Percentage
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%
Average		**3,8336**	**-2,2962**	**64,05%**

1. Work Realization Is Still Below The Plan

This temporary observation is carried out by looking at the trend of work achievement in the last 5 (five) weeks, namely weeks 16 to 20.

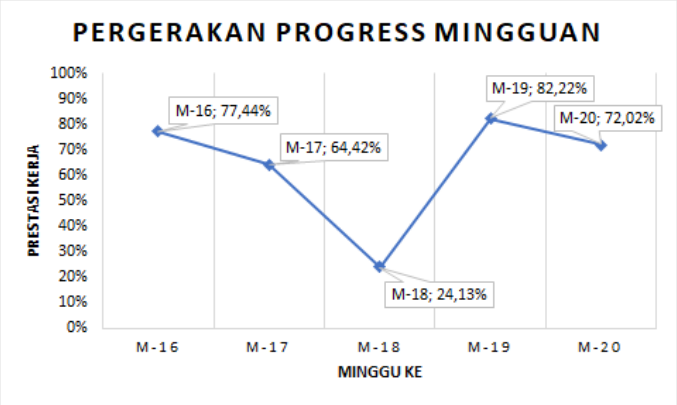

Figure 1. Implementer Achievement Percentage Curve
(Source: Data Processing, 2023)

Looking at the curve above, for the last 5 (five) weeks, the weekly target has never been achieved. Of course, this will cause a buildup of targets in the weeks behind.

2. Comparison Of Weekly Average Gains With Remaining Implementation Time

In the table above it can be seen that the average job gain per week is about 3.8%. The remaining time is 10 (ten) weeks, so it can be concluded that with the current average gain, until the end of the work only obtained about 38%. While the target that still has to be achieved in the remaining time is about 50.6%.

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

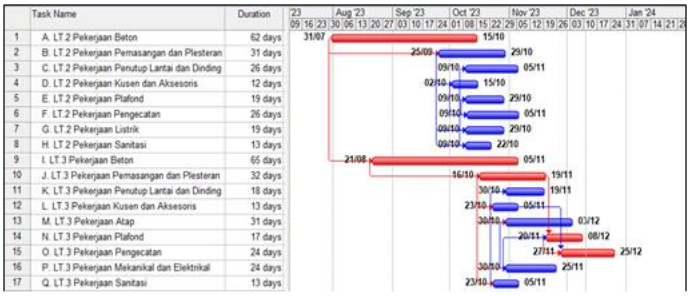

Figure 2. Scheduling with Ms. Project
(Source: Data Processing, 2023)

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

Table 2. 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

From the calculation of the table above, it is found that critical activities occur on the A- I-J-N-O work track which has a Total Slack value equal to 0. So that the Crashing Program can be carried out on these activities, namely:

1. 2nd Floor Concrete Work
2. 3rd Floor Concrete Work
3. 3rd Floor Installation and Plastering Work
4. 3rd Floor Plafond Work
5. 3rd Floor Painting Work

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(Yaqin et al., 2023). 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 3. Breakdown of Work and Labor Cost on Critical Work

No	Jobs	Vol.	Sat	Personnel Cost	Overhead 2.5%	Total Personnel Cost
				(Rp)	(Rp)	(Rp)
1	LT. 2 CONCRETE WORK					
	Concrete Work	299,68	m3	114.275.476	2.856.887	117.132.363
	Screw Fixing	53.168,15	Kg	119.335.913	2.983.398	122.319.311
	Formwork	1.922,10	m2	300.337.736	7.508.443	307.846.179
		AMOUNT		**533.949.124**	**13.348.728**	**547.297.852**
2	LT. 3 CONCRETE WORK					
	Concrete Work	330	m3	125.837.250	3.145.931	128.983.181
	Screw Fixing	67.889,32	Kg	152.377.579	3.809.439	156.187.018
	Formwork	2.436,34	m2	380.690.307	9.517.258	390.207.565
		AMOUNT		**658.905.135**	**16.472.628**	**675.377.763**
3	LT. 3 WALL INSTALLATION AND PLASTERING WORKS					
	Fitting. Red Brick 1/2 Wall 1:5	940,68	m2	59.027.670	1.475.692	60.503.362
	Metal Stud Installation	275,61	m2	22.036.398	550.910	22.587.308
	Installation of Gypsum Board Partition t = 12 mm	551,21	m2	13.049.897	326.247	13.376.144
	Smooth Plastering 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
	GRC Profile List	271,6	m'	5.206.572	130.164	5.336.736
		AMOUNT		**283.255.405**	**7.081.385**	**290.336.790**
4	LT. 3 CEILING WORK					
	Pek. Plafond and Gypsum	740,14	m2	82.825.367	2.070.634	84.896.001
	Pek. Gypsum List	622,11	m1	11.925.849	298.146	12.223.995
		AMOUNT		**94.751.215**	**2.368.780**	**97.119.995**
5	LT.3 PAINTING WORK					

	Pek Wall, Ceiling and Gypum Painting	2.232,03	m2	30.861.163	771.529	31.632.692
	Pek. Painting the new outer wall of Water Shield	475,13	m2	6.531.375	163.284	6.694.659
	Pek. Waterproofing Painting	181,69	m2	2.078.352	51.959	2.130.311
	Pek. Iron Painting	1.104,77	m2	98.020.718	2.450.518	100.471.236
	Pek. Calciplank Painting	55,5	m2	720.390	18.010	738.400
		AMOUNT		**138.211.998**	**3.455.300**	**141.667.298**

(Source: Data Processing, 2023)

It is known that the daily work schedule is as follows:
Monday-Saturday:
Normal Working Hours (7 hours) = Pk. 08.00 - 12.00 WIB
= Pk. 13.00 - 16.00 WIB
Overtime Hours (3 hours) = Pk. 19.00 - 22.00 WIB
Sunday = Holiday
With the same calculation method, the results for all sub-jobs are as follows:

Table 4. Normal and Accelerated Daily Productivity on Critical Work

No.	Jobs	Volume	Sat	Prod. Normal Per Day	Prod. Acceleration Per Day
1	**LT. 2 CONCRETE WORK**				
	Concrete Work	299,68	m3	4,83	6,49
	Screw Fixing	53.168,15	Kg	857,55	1.151,57
	Formwork	1.922,10	m2	31,00	41,63
2	**LT. 3 CONCRETE WORK**				
	Concrete Work	330,00	m3	5,08	6,82
	Screw Fixing	67.889,32	Kg	1.044,45	1.402,55
	Formwork	2.436,34	m2	37,48	50,33
3	**LT. 3 WALL INSTALLATION AND PLASTERING WORKS**				
	Fitting. Red Brick 1/2 Wall 1:5	940,68	m2	29,40	39,47
	Metal Stud Installation 3.4x7.6 Partitions	275,61	m2	8,61	11,57

	Installation of Gypsum Board Partition t = 12 mm	551,21	m2	17,23	23,13
	Smooth Plastering 1:5 + Acian	1.881,36	m2	58,79	78,95
	Benangan	958,31	m'	29,95	40,21
	GRC Profile List	271,60	m'	8,49	11,40
4	**LT. 3 CEILING WORK**				
	Pek. Hollow Frame Ceiling and Gypsum	740,14	m2	43,54	58,46
	Pek. Gypsum List	622,11	m'	36,59	49,14
5	**LT.3 PAINTING WORK**				
	Pek. Wall, Ceiling and Gypsum Painting	2.232,03	m2	93,00	124,89
	Pek. Painting the new outer wall of Water Shield	475,13	m2	19,80	26,58
	Pek. Waterproofing Painting	181,69	m2	7,57	10,17
	Pek. Iron Painting	1.104,77	m2	46,03	61,81
	Pek. Calciplank Painting	55,50	m2	2,31	3,11

(Source: Data Processing, 2023)

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

After calculating the daily productivity of normal duration and acceleration duration, it can be calculated Crash Duration, Crash Cost and Crash Slope. The steps taken are as follows:

3.2.1. 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:

For example, in Hollow Frame Plafond Work 20.40.2 and 40.40.0,2 with 9 mm Gypsum:

Volume = 740,14 m^2

a. Acceleration productivity = 58.46 m /day^2

b. Acceleration Duration = 740,14 / 58,46

= 12.66 ≈ 13 days

With the same calculation, the results are shown in the following table:

Table 5. Duration under Normal and Accelerated Conditions

No.	Jobs	Normal Duration(Days)	Acceleration Duration(Days)
1	2nd Floor Pek. Concrete	62	47
2	3rd Floor Pek. Concrete	65	49
3	3rd Floor Pek. Installationand Plastering	32	24
4	3rd floor Pek. Ceiling	17	13

5	3rd Floor Pek. Painting	24	18

(Source: Data Processing, 2023)

3.2.2. Crash Cost and 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(Manurung, 2018).

An example of calculating overtime costs on wall painting, ceiling and gypsum work is as follows:

1. Direct Cost

Direct costs in the acceleration process are personnel wage costs and overtime costs. Personnel cost data in this study was obtained from the RAB analysis and added to the results of the calculation of personnel overtime wage costs. According to the Labor Law, the calculation of overtime costs is as follows:

a. The first hour's wage is 1.5 times the hourly wage.
b. The wage for each subsequent hour is 2 times the hourly wage.

Table 6. Crash Cost and Crash Slope Calculation Results

No.	Jobs	Normal		Acceleration		Crash Slope (Rp/day)
		Duration (Days)	Personnel Cost (Rp.)	Duration (Days)	Personnel Cost (Rp.)	
1	2nd FloorPek. Concrete	62	547.297.852	47	740.869.789	12.904.796
2	3rd FloorPek. Concrete	65	675.377.763	49	909.162.374	14.611.538
3	3rd Floor Pek. Layingand Plastering	32	290.336.790	24	319.778.215	**3.680.178**
4	3rd floor Pek. Ceiling	17	97.119.995	13	132.621.843	27.148.472
5	3rd Floor Pek. Painting	24	141.667.298	18	189.732.988	8.010.948

(Source: Data Processing, 2023)

From the table above, the lowest Crash Slope is obtained in the work of Lt.3 Installation and Plastering Work amounting to 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:

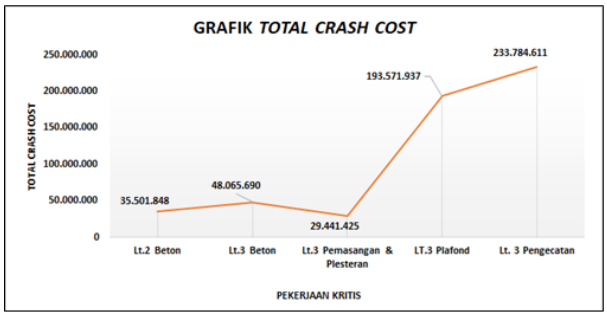

Figure 3. *Crash Slope* Graph on critical work
(Source: Data Processing 2023)

In the graph above shows that acceleration by adding working hours (overtime) 3 hours, the lowest implementation cost is on the work of Lt.3 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.

4. CONCLUSION

In this research can be concluded among others:

1. The results of the study by adding overtime hours for 3 hours per day on all jobs resulted in the Lt.3 Installation & Plastering work with the lowest Cost Slope, with an accelerated duration of 8 days ahead of the original schedule.
2. The additional cost incurred from the Crashing Program on the work mentioned above is Rp. 29,441,425.

5. ADVICE

The author's suggestions for the results of this study are:

1. This acceleration with crashing program can be applied to be an alternative solution to overcome delays.
2. This research can be developed or compared using other methods such as the PERT method.
3. The additional costs resulting from this research can still be reduced further because there is still time remaining from the contract period.

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