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Time and Cost Optimization Analysis of Reservoir Building Work in Wosusokas Regional SPAM Project using Time Cost Trade Off Method

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Abstract: Cost and time optimization is an important aspect of project management that aims to achieve optimal efficiency in the use of resources. Time Cost Trade Off (TCTO) method is often used to manage the relationship between time and cost in project completion. This research analyzes cost and time optimization on construction projects using Primavera P6 software. In optimization with the addition of working hours, 4 alternatives were carried out, namely the addition of 1 hour, 2 hours, 3 hours, and 4 hours of work, the re-sults obtained were a shorter duration but the total cost was getting bigger. Whereas in the alternative of adding workers as many as 1 worker and 2 workers, the optimization results obtained a shorter duration and a reduced total cost. Thus, the TCTO method and the use of Primavera P6 proved ef-fective in identifying the most efficient optimization strategy to achieve pro-ject success on time and within budget.

Keywords: Cost Optimization, Time Optimization, Time Cost Trade Off (TCTO), Pri-Mavera P6, Alternatives.

Introduction

The 17-kilometer pipeline, that connects three reservoirs and a booster in Plensungan, will deliver water to offtakes in Mojolaban, Dagen, and Plensungan. Open Cut and HDD transmission pipeline techniques are applied particularly for the line that crosses the river. The project encounters difficulties in managing its resources, including workers and time, which can lead to issues if not handled effectively (Friederich, 2021; Yu, 2021). Cost variables play an important role when constructing a project, in along with time and resource variables (Le, 2020; Olsen, 2020). One of the key components of management is cost, which needs to be minimized wherever feasible. Because there is a direct correlation between the project's expenses and its completion time, cost control must take the time component into consideration (Priyo dan Paridi, 2018). Proper time and cost estimation and project optimization are needed to overcome this challenge (Dev, 2020; Doelman, 2020).

Optimization is necessary in order to estimate the time and cost of a project. Accelerating the time of each project activity from the usual will definitely accelerate the project completion time (Jouhari, 2019; Y. Wang, 2019). However, shortening the duration of these tasks can also have an impact on project costs, essentially because each shortened task has a longer duration than the others, raising the project's overall cost above average. When there's a need to accelerate the implementation timeline, the quickest possible implementation period at the highest feasible expense is referred to as a crash program. To accelerate a project, it is not necessary to accelerate all activities but only the critical ones (Pickard, 2019; Z. Wang, 2019). So, the acceleration of the implementation time of critical activities is what can affect the acceleration of the project implementation time, but to accelerate the project implementation time with critical activities there is a limit. Here are the steps to optimize time and cost with a crash program:

1. The activities are tabulated by marking the activities through the critical path. Crash programs are only carried out on critical activities.
2. Calculate the time and cost of each activity both normal and crash.
3. The additional cost (cost slope) of each activity is calculated per day.

There are several alternatives that can be used in accelerating the project completion duration, namely the addition of working hours, division of shifts, addition of labor, addition of tools, and replacement of implementation methods. The addition of working hours (overtime) is very often done because it empowers the resources that already exist in the field, overtime hours are carried out after normal working hours are completed (Sofia and Putri, 2021). The addition of working hours (overtime) is done by adding the duration of working hours as desired. The greater the additional duration, the decrease in productivity (Soeharto, 1999). The addition of labor to an activity must not interfere with labor for other activities that are running at the same time. In addition, good supervision is also necessary. This is because a crowded workspace with low supervision will reduce worker productivity (Septian and Samsul, 2017).

In this time cost trade off analysis, with the change in project completion time, the costs will also change. If the implementation time is accelerated, the direct cost of the project will increase and the indirect cost of the project will decrease.

Methodology

Time Cost Trade Off method is used to optimize project cost and time and determine the most efficient alternative. Data analysis will be carried out using Primavera Pro-ject Planner P6 Program, which can calculate automatically and provide At Comple-tion Cost and At Completion Duration results before and after optimization. Data analysis using Primavera P6 Program includes three stages:

1. Preparation of baseline scheduling: Using the project Time Schedule and Budget Plan (RAB) data to plan the project schedule and cost.
2. Calculation of acceleration of work duration: Using the list of critical activities, nor- mal cost, and normal duration data from Primavera P6 analysis to calculate the work duration.
3. Preparation of optimization scheduling: Using the project scheduling data after optimization by the method of adding working hours and labor to determine the schedule and cost after optimization.

Result and Discussion

The calculations to be carried out, namely the analysis of time and cost optimization in the Wosusokas Mojolaban Reservoir Off taker and Dagen Reservoir Off taker Regional SPAM Project. Data analysis was carried out with the help of the Primavera Project Planner P6 program. Activities on the critical trajectory obtained from scheduling using the Primavera Project Planner P6 program are described in table 1 below.

Table 1. Critical Activities in the SPAM Regional Wosusokas Mojolaban Reservoir off taker and Dagen Reservoir off taker projects

Code	Job Description	Normal Duartion (Days)	Volume	Unit
3.8	Other Works Mojolaban Pump House	30	45	m
3.7	MEP Works Mojolaban Pump House	41	130	unit
4.9	MEP Works Mojolaban Generator House	34	140	unit
9.10	Other Works Dagen Pump House	30	45	m
9.8	MEP Works Dagen Pump House	34	144	unit
9.9	Distribution Pump Dagen Pump House	30	10	unit
10.9	MEP Works Dagen Generator House	32	106	unit

Discussion

Additional Working Hours. Additional working hours are carried out by increasing overtime hours in accordance with Government Regulation of the Republic of Indonesia Number 35 of 2021. The maximum overtime limit is 4 hours per day and 18 hours per week. Overtime wages are set as 1.5 times the wage of one normal hour of work for the first hour, and 2 times the wage of one normal hour of work for each subsequent hour, plus overtime costs from the previous hour. The standards used in the calculation are as follows.

a. The number of additional overtimes working hours, using several variations of 1, 2, 3, and 4 hours/day.

b. Overtime work productivity of 75%.

Crashing. Addition of 1 hour of overtime to work 3.8 Other Works Mojolaban Pump House.

1) *Normal cost*

a. Volume of work	= 45 m
b. Wages	= Rp17.589,40 /m
c. *Normal duration*	= 30 days
d. *Normal cost*	= (a x b)
	= 45 x Rp17.589,40
	= Rp791.523,00

2) *Crash duration*

e. Daily Productivity	= (a/c)
	= 45/30 = 1,5 m/day
f. Productivity per hour	= (e/8)
	= 1,5/8 = 0,1875 m/jam
g. Daily crash productivity	= (e + (1 x f x 75%))
	= (1,5 + ([additional hours] x 0,1875 x 0,75))
	= 1,6406 m/day
Crash duration	= (a/g)
	= 45/1,6406
	= 27,4286 ≈ 27 days

3) Overtime Labor Index

Overtime volume	= (f x h)
	= 0,1875 x 27 = 5,0625 m
Overtime labor index	= volume when overtime x labor coefficient
Foreman Index	= 5,0625 x 0,0268 = 0,1357 OH
Worker Index	= 5,0625 x 0,1606 = 0,8130 OH

4) *Crash Cost*

h. Normal hourly wage	= (b x f)
	= Rp17.589,40 x 0,1875 = Rp3.298,01
i. 1 hour overtime pay	= (1,5 x i) + (2 x i x [additional hours])
	= (1,5 x 3.298,01) + (2 x 3.298,01 x 1)
	= Rp11.543,04
j. Total overtime pay	= (h x j)
	= 27 x Rp11.543,04 = Rp311.662,18
k. Total *crash cost*	= (k + d)
	= Rp311.662,18 + Rp791.523,00
	= Rp1.103.185,18

5) *Cost slope*

l. *Cost slope*

$$= \frac{\textit{Crash cost} - \textit{Normal cost}}{\textit{Normal duration} - \textit{Crash duration}}$$

$$= \frac{(l-d)}{(c-h)} = \frac{Rp1.103.185,18 - Rp791.523,00}{30-27}$$

= Rp103.887,39

The formula for calculating *crash* productivity for each additional hour uses the formula listed in table 2 and the recapitulation of calculations for the addition of 1 hour of over- time is listed in table 3. After the optimization calculation with the *Time Cost Trade Off* (TCTO) method has been carried out and has entered the new duration and cost into each work activity, the next step is to compare the duration and cost after crashing with the initial duration and cost.

Table 2. *Crash* Productivity Formula for Each Additional Hour

No.	Conditions	*Crash* Productivity	Overtime Wages
1	Addition of 1 Hour	prod. Daily + (1 x prod. per hour x 75%)	(1.5 x normal hourly wage)+(2 x normal hourly wage x 1)
2	Addition of 2 Hours	prod. Daily + (2 x prod. per hour x 75%)	(1.5 x normal hourly wage)+(2 x normal hourly wage x 2)
3	Addition of 3 Hours	prod. Daily + (3 x prod. per hour x 75%)	(1.5 x normal hourly wage)+(2 x normal hourly wage x 3)
4	Addition of 4 Hours	prod. Daily + (4 x prod. per hour x 75%)	(1.5 x normal hourly wage)+(2 x normal hourly wage x 4)
5	Addition of n Hours	prod. Daily + (n x prod. per hour x 75%)	(1.5 x normal hourly wage)+(2 x normal hourly wage x n)

Table 3. Recapitulation of Crash Duration, Crash Cost, and Cost Slope Calculations with the Addi-tion of 1 Overtime Hour

No.	Job Description	*Normal Duration* (Days)	*Normal Cost* (Rp)	*Crash Duration* (Days)	*Crash Cost* (Rp)	*Cost Slope* (Rp)
1	Other Works Mojolaban Pump House	30	791.523,00	27	311.662,18	103.887,39
2	MEP Works Mojolaban Pump House	41	17.826.250,00	37	7.038.107,85	1.759.526,96
3	MEP Works Mojolaban Generator House	34	19.197.500,00	31	7.657.826,29	2.552.608,76
4	Other Works Dagen Pump House	30	791.523,00	27	311.662,18	103.887,39
5	MEP Works Dagen Pump House	34	19.746.000,00	31	7.876.621,32	2.625.540,44
6	Distribution Pump Dagen Pump House	30	992.500,00	27	390.796,88	130.265,63
7	MEP Works Dagen Generator House	32	14.535.250,00	29	5.762.999,51	1.920.999,84

Addition of Workers. The addition of labor is the addition of workers without increas- ing working hours. In planning the addition of workers, it is necessary to pay attention to the available workspace so as not to interfere with other ongoing activities.

Crashing. Addition of 1 worker to work 3.8 Other Works Mojolaban Pump House.

1) Job Data

a. Volume of work = 45 m

b. Wages = Rp17.589,40 /m

c. Normal duration = 30 hari

d. Labor coefficient

Foreman = 0,0268

Worker = 0,1606

e. Unit price of labor

Foreman = Rp111.000

Worker = Rp91.0000

2) Work capacity per day for workers

Worker's work capacity $= \frac{1}{\text{Labor coefficient}}$

$= \frac{1}{0{,}1606}$ = 6,2267 m/day

Foreman's work capacity $= \frac{1}{\text{Labor coefficient}}$

$= \frac{1}{0{,}0268}$ = 37,3134 m/day

Labor index per day

Worker Index $= \frac{\text{volume of work}}{\text{work capacity x work duration}}$

$= \frac{45}{6{,}2267 \text{ x } 30} = \mathbf{0,2409\ OH}$

Foreman Index $= \frac{\text{volume of work}}{\text{work capacity x work duration}}$

$= \frac{45}{37{,}3134 \text{ x } 30} = \mathbf{0,0402\ OH}$

3) Normal cost

Wage price = labor index x unit price

Foreman = 0,0402 x Rp111.000 = Rp4.462,20

Worker = 0,2409 x Rp91.000 = Rp21.921,90

Normal cost = Wage price x duration

= (Rp4.462,20 + Rp21.921,90) x 30

= Rp791.523,00

Addition of 1 Worker

4) Crash duration

Crash duration $= \frac{\text{volume of work}}{\text{work capacity x (index+[addition of workers])}}$

$= \frac{45}{6{,}2267 \text{ x } (0{,}2409+1)} = \mathbf{6\ days}$

5) Crash cost

Wage price = Unit price x (index + [addition of workers])

= Rp91.000 x (0,2409 + 1)

= Rp112.921,90

Crash cost = Wage price x crash duration

= Rp112.921,90 x 6

= Rp1.370.304,60

Total crash cost = Normal cost + crash cost

= Rp791.523,00 + Rp1.370.304,60

= Rp2.161.827,60

6) Cost slope $= \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal duration} - \text{Crash duration}}$

$$= \frac{Rp1.370.304{,}60 - Rp791.523{,}00}{30-6} = \boldsymbol{Rp24.115{,}90}$$

The recapitulation of calculations for additional workers is listed in Table 4. After the optimization calculation with the *Time Cost Trade Off* (TCTO) method has been carried out and has entered the new duration and cost into each work activity, the next step is to compare the duration and cost after crashing with the initial duration and cost.

Table 4. Recapitulation of Crash Duration, Crash Cost, and Cost Slope Calculations with the Addition of 1 Worker.

No.	Job Description	*Normal Duration* (Days)	*Normal Cost* (Rp)	*Crash Duration* (Days)	*Crash Cost* (Rp)	*Cost Slope* (Rp)
1	Other Works Mojolaban Pump House	30	791.523,00	6	1.370.304,60	24.115,90
2	MEP Works Mojolaban Pump House	41	17.826.250,00	22	20.807.304,88	156.897,63
3	MEP Works Mojolaban Generator House	34	19.197.500,00	21	22.588.279,41	260.829,19
4	Other Works Dagen Pump House	30	791.523,00	6	1.370.304,60	24.115,90
5	MEP Works Dagen Pump House	34	19.746.000,00	21	22.927.058,82	244.696,83
6	Distribution Pump Dagen Pump House	30	992.500,00	3	1.329.250,00	11.225,00
7	MEP Works Dagen Generator House	32	14.535.250,00	18	17.374.078,13	202.773,44

Calculation of Direct and Indirect Costs. Direct costs include all costs directly related to the execution of work in the field, such as material or material costs, workers' wages, equipment costs, and subcontractor costs. In contrast, indirect costs are costs incurred for each project work, but not directly related to activities in the field, such as overhead costs and profits. The amount of *overhead* costs and *profit* used, which is 15% (Profit 10% and Overhead 5%). The following is a calculation of direct and indirect costs be- fore and after optimization.

1) Mojolaban Reservoir Offtaker
a) Cost Budget Recapitulation = Rp10.668.935.014,37
b) *Profit* (10%) = Rp10.668.935.014,37 x 10%
= Rp1.066.893.501,44
c) *Overhead* (5%) = Rp10.668.935.014,37 x 5%
= Rp533.446.750,72

1. Project cost under normal conditions
Duration = 371 hari
Direct cost = Rp10.668.935.014,37
Indirect cost
Overhead = Rp10.668.935.014,37 x 5%

= Rp533.446.750,72

Profit = Rp10.668.935.014,37 x 10%

= Rp1.066.893.501,44

Overhead + Profit = Rp533.446.750,72 + Rp1.066.893.501,44

= Rp1.600.340.252,16

Overhead cost per day = *Overhead*/duration

= Rp533.446.750,72/371

= Rp1.437.861,86

Total Cost = Direct cost + Indirect cost

= **Rp10.668.935.014,37 + Rp1.600.340.252,16**

= Rp12.269.275.266,53

In table 5, a recapitulation of the calculation results of duration, direct costs, indirect costs, and total costs under normal conditions and after optimization

Table 5. Comparison of Duration, Direct Cost, Indirect Cost, and Total Cost under Normal Conditions and after Optimization

No.	Conditions	Duraion (days)	Direct costs	Indirect costs	Total cost
1	Normal	371	Rp 10.668.935.014,37	Rp 1.600.340.252,16	Rp 12.269.275.266,53
2	1 Hour Overtime	368	Rp 10.683.437.589,55	Rp 1.596.026.666,57	Rp 12.279.464.256,12
3	2 Hours Overtime	366	Rp 10.690.409.895,22	Rp 1.593.150.942,85	Rp 12.283.560.838,07
4	3 Hours Overtime	364	Rp 10.696.547.173,04	Rp 1.590.275.219,12	Rp 12.286.822.392,16
5	4 Hours Overtime	363	Rp 10.701.065.748,49	Rp 1.588.837.357,26	Rp 12.289.903.105,75
6	Addition of 1 Worker	358	Rp 10.670.862.427,35	Rp 1.581.648.047,95	Rp 12.252.510.475,30
7	Addition of 2 Worker	352	Rp 10.673.027.969,23	Rp 1.573.020.876,78	Rp 12.246.048.846,01
8	Difference (1) and (2)	3	Rp 14.502.575,18	Rp 4.313.585,59	Rp 10.188.989,59
9	Difference (1) and (3)	5	Rp 21.474.880,85	Rp 7.189.309,31	Rp 14.285.571,54
10	Difference (1) and (4)	7	Rp 27.612.158,67	Rp 10.065.033,03	Rp 17.547.125,64
11	Difference (1) and (5)	8	Rp 32.130.734,12	Rp 11.502.894,89	Rp 20.627.839,23
12	Difference (1) and (6)	13	Rp 1.927.412,98	Rp 18.692.204,20	-Rp 16.764.791,22
13	Difference (1) and (7)	19	Rp 4.092.954,86	Rp 27.319.375,37	-Rp 23.226.420,51

In table 6 attached recapitulation of the calculation results with the addition of working hours.

Table 6. Recapitulation of Calculation Results with Additional Working Hours

No.	Condition	Durations (days)	Total Cost
1	Normal	371	Rp 12.269.275.266,53
2	1	368	Rp 12.279.464.256,12
3	2	366	Rp 12.283.560.838,07
4	3	364	Rp 12.286.822.392,16
5	4	363	Rp 12.289.903.105,75

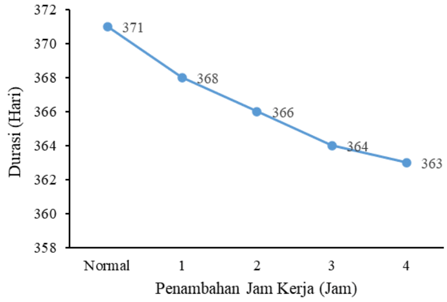

Figure 1. Graph of Duration Relation to Additional Working Hours

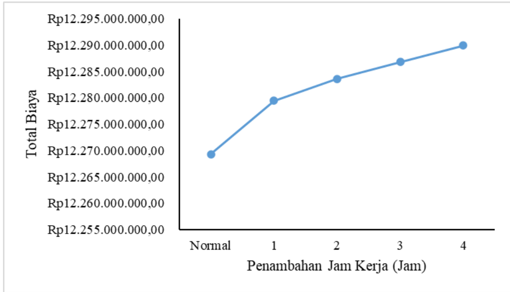

Figure 2. Graph of the Relation of Total Cost to Additional Working Hours

In Figure 1, it can be seen that the greater the addition of working hours, the shorter the project duration, while Figure 2 shows that the greater the addition of working hours, the total cost required will increase or be greater. In table 7 attached is a recapitulation of the calculation results with the addition of workers.

Table 7. Recapitulation of Calculation Results with the Addition of Workers

No.	Condition	Duration (days)	Total Cost
1	Normal	371	Rp 12.269.275.266,53
2	Addition of 1 Worker	358	Rp 12.252.510.475,30
3	Addition of 2 Worker	352	Rp 12.246.048.846,01

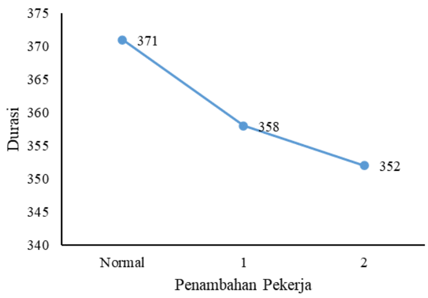

Figure 3. Graph of Duration Relation to Additional Working Hours

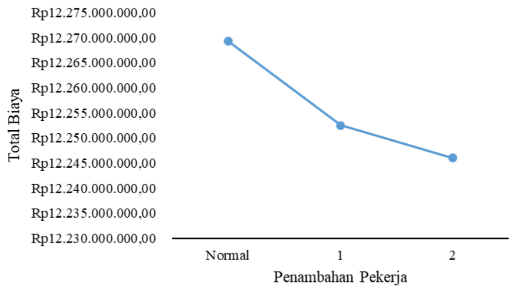

Figure 4. Graph of the Relation of Total Cost to Additional Working Hours

Figure 3 shows that the greater the addition of working hours, the shorter the project duration, while Figure 4 shows that the greater the addition of working hours, the total cost required will decrease or decrease. A recapitulation of the results of cost and time efficiency calculations on the project is shown in table 8 below.

Table 8. Recapitulation of Calculation Results with the Addition of Working Hours and Workers

No.	Kondisi	Efisiensi Biaya (%)	Efisiensi Waktu (%)
1	1 Jam Lembur	-0,083	0,809
2	2 Jam Lembur	-0,116	1,348
3	3 Jam Lembur	-0,143	1,887

No.	Kondisi	Efisiensi Biaya (%)	Efisiensi Waktu (%)
4	4 Jam Lembur	-0,168	2,156
5	Penambahan 1 Pekerja	0,137	3,504
6	Penambahan 2 Pekerja	0,189	5,121

The addition of overtime hours shows that cost efficiency is negative, meaning the total cost increases, but time efficiency is positive, with the project duration decreasing.

Conclusion

The optimization results show that the addition of working hours (overtime) and workers can shorten the project duration but increase the total cost. The addition of working hours (overtime) and workers tends to increase direct costs but reduce indirect costs of the project because it shortens the duration of work on the critical path. In optimization with the addition of working hours, 4 alternatives are carried out, namely the addition of 1 hour, 2 hours, 3 hours, and 4 hours of work, the results obtained are that the duration is getting shorter but the total cost is getting bigger. Whereas in the alternative of adding workers as many as 1 worker and 2 workers, the optimization results obtained a shorter duration and a reduced total cost.

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