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Cost and Duration Optimization at Building C of Dharmais Cancer Hospital Jakarta with TCTO Method Using Primavera P6 Analysis

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Abstract: In construction projects, cost and duration are important aspects but there are several factors that become obstacles. With these constraints, the project needs to organize its project management to keep it running according to the contract. The method that can be used to manage these deviations is TCTO (Time Cost Trade Off). There are three scenarios used in this study, namely the addition of working hours, the addition of labor, and a combined (addition of working hours and labors), using the help of Primavera P6. This research aims to analyze the estimated total duration and cost obtained after optimization, compare the total duration and cost obtained before and after optimization, and recommend the most economical alternative among the scenarios carried out. The results of the optimization analysis carried out using additional working hours (scenario 1) are 611 days and an increase in costs; while with additional labor (scenario 2) are 632 days and a decrease in costs; and with a combination (scenario 3) are 611 days and a decrease in costs. The most economical alternative from this study is to use scenario 2 because it reduces the duration and cost of the initial cost budget plan of the project.

Keywords: Optimization, Primavera P6, Time Cost Trade Off.

Introduction

In construction projects, cost and duration are important aspects that are usually considered the most in tendering documents. The document tendering stage includes the stage where contractors will compete with each other to submit bids with the fastest implementation duration and the most optimal cost. The contractor will be selected by the owner either directly or with the help of a construction management consultant. In project implementation, there are several factors that will certainly become obstacles. The factors and obstacles posed will differ based on the type and method of construction being carried out. The obstacles that often occur in construction are related to funds, quality, time, and labor. With these obstacles, the project needs to organize its project management smartly to keep it running according to the contract. The method that can be used to manage these deviations is TCTO (Time Cost Trade Off). TCTO is a method that is done by adding variables and making certain alternatives to a project (Muharani et al., 2020).

The alternative can be done by creating scenarios in the form of increasing the number of labors, project working hours, and procuring labors shifts. This method is also used to reduce the project duration determined through critical path analysis at the least cost (Elbeltagi, 2009). The critical path is a trajectory of activities with zero float value in a scheduling (Simorangkir et al., 2020). In the digital era, the critical path can be determined by processing data using the help of scheduling tools in the form of Primavera P6 software. Primavera P6 software is a special tool that is used to ease the process of planning, scheduling, and controlling activities and resources in the form of labor in the implementation of a project's work (Rahmawan et al., 2020).

This research will optimize the cost and duration of the project at Building C of Dharmais Cancer Hospital Jakarta with the TCTO method with the problem formulation to analyze the estimated total duration and cost obtained from completing the project after optimization, comparing the total duration and cost obtained from completing the construction project before and after optimization, and recommending the most economical alternative among the optimization scenarios carried out.

Methodology

The construction project of Building C of Dharmais Cancer Hospital Jakarta is located at Letjen S. Parman No. 84-86, Slipi, Palmerah, West Jakarta City, DKI Jakarta. Overall, this construction project consists of 18 floors and 3 basement floors with a building area of 35,680 m^2 on a land area of 5,083 m^2. In the implementation of the work, the project site was divided into five zones, namely zones 1A, 1B, 2A, 2B, and 3 as shown in Figure 1. This division of zones was enforced to consider the convenience factor in the field implementation process.

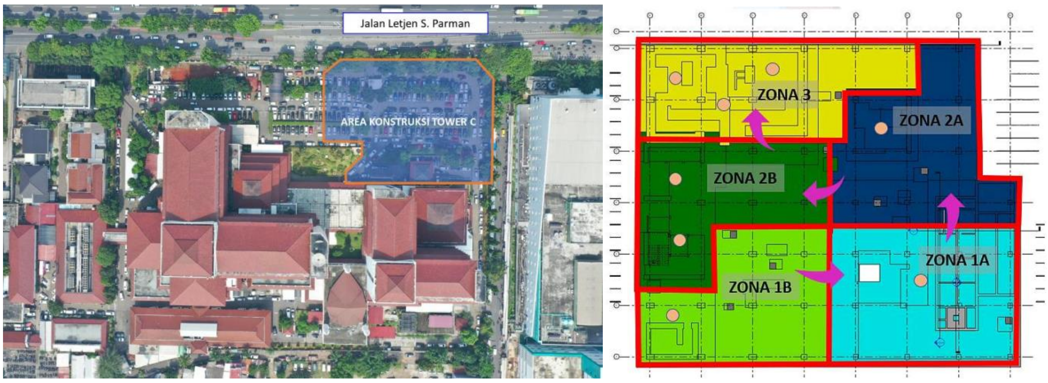

Figure 1. Site Plan of Building C Project of Dharmais Cancer Hospital Jakarta

The method used is time cost trade off with three scenarios. Secondary data required are in the form of analysis of unit price of work, cost budget plan, work volume, s-curve, and work weight. To make it easier to understand the procedure, the research stages will be explained schematically in Figure 2.

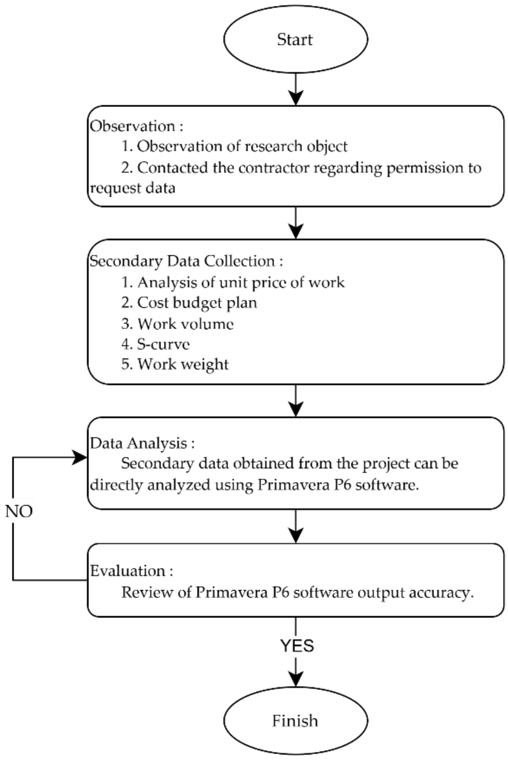

Figure 2. Research flowchart

Result and Discussion

This section will explain in detail about the optimization of project cost and duration in Building C of Dharmais Cancer Hospital Jakarta. Data processing is done with the help of scheduling tools in the form of Primavera P6 software. This scheduling tool will calculate the amount of cost and duration before and after optimization as a whole. However, in this study, researchers limited the problem by optimizing the critical path only.

Additional Working Hours Scenario

The addition of working hours are carried out in accordance with applicable laws and regulations. In document KEP.102/MEN/VI/2004 concerning overtime working time and overtime pays. In the first hour, the overtime work pay will increase by 1.5 times the normal 1-hour pay of the labor, while in each subsequent hour, the overtime work pay will increase by 2 times the normal 1-hour pay of the labor. In addition, according to the Government Regulation document of the Republic of Indonesia No. 35 of 2021, overtime work can only be carried out for a maximum of four hours on each day.

The example calculation is carried out on the lightweight brickwork of basement 1 with the addition of 1 working hour on each shift.

A. Normal working hours = 16 hours/day
= 8 hours/shift
= 2 shifts/day

B. Productivity reduction factor = 0,75
In the calculation of overtime productivity, there will be a decrease in productivity caused by fatigue, visibility, and night air (Arvianto et al., 2017).

C. Calculations
1. Data
a) Volume = 2781 m^2
b) Normal duration = 21 days
c) Foreman pay = Rp218.291
d) Head of mason pay = Rp206.315
e) Mason pay = Rp189.845
f) Laborer pay = Rp180.462

2. Labor Coefficients
Foreman = 0,003
Head of mason = 0,013
Mason = 0,130
Laborer = 0,671

3. Labor Index
g) Labor index = Volume × Labor coefficients
Foreman = 2781 × 0,003 = 8,34 person
Head of mason = 2781 × 0,013 = 36,16 person
Mason = 2781 x 0,130 = 361,58 person
Laborer = 2781 x 0,671 = 1866,28 person

4. Normal Cost
h) Labor unit price = Labor coefficients × Unit pays
Foreman = 0,003 × Rp218.291 = Rp654
Head of mason = 0,013 × Rp206.315 = Rp2.682

Mason	= 0,130 × Rp189.845	= Rp24.680
Laborer	= 0,671 × Rp180.462	= Rp121.090 +
	Total	= Rp149.106

i) Normal cost = Labor unit price × Volume = h × a
= Rp149.106 x 2781,35
= Rp414.717.958

5. Labor Productivity

j) Daily productivity $= \frac{\text{Volume}}{\text{Normal Duration}} = \frac{a}{b}$

$= \frac{2781}{21}$

= 132,45 m^3/day

k) Hourly productivity $= \frac{\text{Daily productivity}}{\text{Normal working hours}}$

$= \frac{132{,}45}{16}$

= 8,28 m^3/hour

6. Crash Productivity

= Addition of overtime hours for each shift × Hourly productivity × Productivity reduction factor

l) Crash productivity shift 1 = 1 × 8,28 × 0,75 = 6,21 m^3/shift

m) Crash productivity shift 2 = 1 × 8,28 x 0,75= 6,21 m^3/shift

n) Crash daily productivity = Daily productivity + Crash productivity shift 1 + Crash productivity shift 2
= j + l + m
= 132,45 + 6,21 + 6,21
= 144,86 m^3/day

7. Crash Duration

o) Crash Duration $= \frac{\text{Volume}}{\text{Crash Daily Productivity}} = \frac{a}{n} = \frac{2781}{144{,}86}$ = 19,2 ~ 20 days

8. Crash Labor Index

p) Overtime volume = Hourly productivity × Crash duration = k × o
= 8,28 × 20
= 165,56 m^2

q) Crash labor index on each shift
= Overtime volume × Labor coefficients

Foreman	= 165,56 × 0,003	= 0,497	person
Head of mason	= 165,56 × 0,013	= 2,152	person
Mason	= 165,56 × 0,130	= 21,522	person
Laborer	= 165,56 × 0,671	= 111,088	person

9. Labor pays

Normal hourly pays = Labor unit price x Hourly productivity = g × j

r) Normal hourly pay shift 1 = Rp149.106 × 8,28

= Rp1.234.279

s) Normal hourly pay shift 2 = Rp149.106 × 8,28
= Rp1.234.279

Crash hourly pay = Overtime pay factor × Normal hourly pay

t) Crash hourly pay shift 1 = 1,5 × r = 1,5 x Rp1.234.279
= Rp1.851.419

u) Crash hourly pay shift 2 = 1,5 × s = 1,5 × Rp1.234.279
= Rp1.851.419

v) Total labor pays
= Crash duration × Crash hourly pay on each shift
= o × (t + u)
= 20 × (Rp1.851.419 + Rp1.851.419)
= Rp74.056.778

10. Crash Cost

w) Crash Cost = Normal Cost + Total labor pays = h + v
= Rp414.717.958 + Rp74.056.778
= Rp488.774.735

11. Cost Slope

x) Cost Slope $= \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Duration} - \text{Crash Duration}} = \frac{w - i}{b - o}$

$= \frac{\text{Rp}488.774.735 - \text{Rp}414.717.958}{21 - 20}$

= Rp74.056.778

Additional Labors Scenario

The addition of labors to a project will affect work productivity. If the amount of labor added does not consider the available workspace, then productivity will decrease directly proportional to the limited workspace.

An example of calculation is carried out on the lightweight brickwork of basement 1 with the addition of 1 mason and 5 laborer.

A. Calculations

1. Data

a) Volume = 2781 m^2

b) Normal duration = 21 days

c) Foreman pay = Rp218.291

d) Head of mason pay = Rp206.315

e) Mason pay = Rp189.845

f) Laborer pay = Rp180.462

2. Labor Coefficients

Foreman = 0,003

Head of mason = 0,013

Mason	= 0,130		
Laborer	= 0,671		

3. Labor Index

g) Labor index = Volume × Labor coefficients

Foreman	= 2781 × 0,003	= 8,34	person
Head of mason	= 2781 × 0,013	= 36,16	person
Mason	= 2781 x 0,130	= 361,58	person
Laborer	= 2781 x 0,671	= 1866,28	person

h) Daily labor index $= \frac{\text{Labor index}}{\text{Normal duration}} = \frac{g}{b}$

Foreman	= 8,34/21	= 0,40	person
Head of mason	= 36,16/21	= 1,72	person
Mason	= 361,58/21	= 17,22	person
Laborer	= 1866,28/21	= 88,87	person

4. Normal Cost

i) Labor unit price = Labor coefficients × Unit pays

Foreman	= 0,003 × Rp218.291	= Rp654
Head of mason	= 0,013 × Rp206.315	= Rp2.682
Mason	= 0,130 × Rp189.845	= Rp24.680
Laborer	= 0,671 × Rp180.462	= Rp121.090 +
	Total	= Rp149.106

j) Normal cost = Labor unit price × Volume = i × a
= Rp149.106 x 2781,35
= Rp414.717.958

5. Crash Duration

k) Crash Duration

$$= \frac{\text{Volume} \times \text{Labor coefficients}}{\text{Labor index} + \text{Number of labor additions}}$$

Mason $= \frac{2781 \times 0{,}130}{17{,}22+1} = 19{,}85$ days

Laborer $= \frac{2781 \times 0{,}671}{88{,}87+2} = 19{,}88$ days

The crash duration used is the longest duration which is 19,88~20 Days.

6. Crash Labor index

l) Crash labor index = Crash duration × Daily labor index = k × h

Foreman	= 20 × 0,40	= 7,95	person
Head of mason	= 20 × 1,72	= 34,44	person
Mason	= 20 × 17,22	= 344,36	person
Laborer	= 20 × 88,87	= 1777,41	person

m) Additional labor index= Crash duration × Number of labor additions

Mason	= 20 × 1	= 20	person

Laborer	= 20 × 5	= 100	person

7. Crash Cost

n) Crash labor pays = Unit pays × (Daily labor index + Number of labor additions)

Foreman	= Rp218.291 × (0,40)	= Rp86.734
Head of mason	= Rp206.315 × (1,72)	= Rp355.230
Mason	= Rp189.845 × (17,22+1)	= Rp3.456.571
Laborer	= Rp180.462 × (88,87+5)	= Rp16.940.092 +
	Total	= Rp20.840.629

o) Crash cost = Crash labor pays × Crash duration = n x k
= Rp20.840.629 × 20
= Rp416.812.584

8. Cost Slope

p) Cost Slope $= \frac{\text{Crash Cost}-\text{Normal Cost}}{\text{Normal Duration}-\text{Crash Duration}} = \frac{o-j}{b-k}$

$= \frac{\text{Rp}416.812.584-\text{Rp}414.717.958}{21-20}$

= Rp2.094.626

Combined Scenario

In the combined scenario, a project conducts an alternative selection of the Time Cost Trade Off (TCTO) method with 2 scenarios in its work. However, there is a requirement that needs to be applied to the combined scenario, namely that one job can only be carried out in one optimization scenario. This is considering, if on one job additional working hours and labor are carried out at the same time, then the fatigue factor and limited space for movement reduce the efficiency of project implementation.

Combined optimization was carried out by comparing the cost and duration between the normal conditions, scenario 1, and scenario 2 that had been carried out. The scenario chosen was the one with the lowest crash cost for the works under review. Therefore, it is possible that the optimization performed on the critical path has different scenarios for each of the works.

Calculation of Cost

In the project document used as a reference, overhead costs and project profits have not been included in the cost budget plan. Therefore, according to the price adjustment procedure with document number SOP/UPM/DJBM-116 (2017), cost budget plan that do not include the amount of the coefficient value can use a fixed coefficient of 0.15.

The project duration after optimization can affect the indirect costs of the project. This is because indirect cost optimization uses the normal indirect cost reference to measure cost increases in making decisions without considering profit.

Calculations

1. Project cost normal condition

a)	Duration	= 653 days
b)	Direct cost	= Rp427.357.838.000
c)	Indirect cost	
	Overhead	= 5% × b
		= Rp21.367.891.900
	Profit	= 10% × b
		= Rp42.735.783.800
	Total	= Rp64.103.675.700
d)	Daily overhead cost	= c(overhead)/a
		= Rp32.722.652
e)	Direct + Indirect cost	= b + c(total)
		= Rp491.461.413.700
f)	Tax (10%)	= 10% × e
		= Rp49.146.151.370
g)	Total project cost	= e + f
		= Rp540.607.665.070

2. Project cost with scenario 1 optimization (Additional working hours)

h)	Crash duration	= 611 days
i)	Acceleration duration	= 653 – 611 = 42 days
j)	Direct cost	= Rp429.055.037.349
k)	Indirect cost	
	Overhead	= Crash duration × Daily overhead cost
		= h × d
		= 611 × Rp32.722.652
		= Rp19.993.540.507
	Profit	= c(profit)
		= Rp21.367.891.900
	Total	= Rp62.729.324.307
l)	Direct + Indirect cost	= j + k(total)
		= Rp491.784.361.656
m)	Tax (10%)	= 10% × e
		= Rp49.178.436.166
n)	Total project cost	= l + m
		= Rp540.962.797.821

Cost calculations were applied to all optimization scenarios used in the study, so the results of the study can be displayed in Table 1.

Table 1: Recapitulation of normal and optimization total project cost

No.	Condition	Duration (Days)	Total Project Cost (Rp)
1	Normal	653	540.607.665.070
2	Additional Working Hours	611	540.962.797.821
3	Additional Labors	632	539.887.693.054
4	Combined	611	540.525.412.830
5	Reduction of (1) and (2)	42	-355.132.751
6	Reduction of (1) and (3)	21	719.972.016
7	Reduction of (1) and (4)	42	82.252.240

Note: The negative values that shown in Table 1 in the total project cost column indicate that the optimization number is overcost of the normal cost.

S-Curve

The S-curve is made based on the progress of work each week on a project. The S-curve in this study is shown in Figure 3.

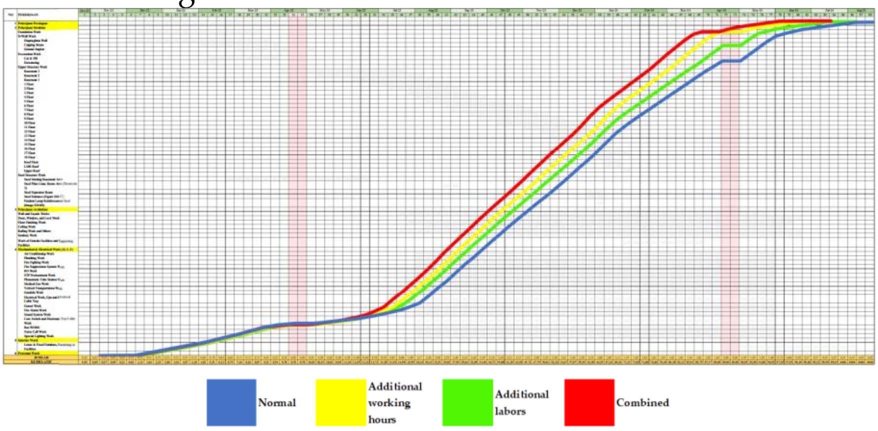

Figure 3. S-Curve

Conclusion

The results of the optimization analysis carried out using the additional working hours (scenario 1) are 611 days (42 days faster than normal time) and an increase in cost to Rp540,962,797,821; while with the additional labors (scenario 2) are 632 days (21 days faster than normal time) and a decrease in cost to Rp539,887,693,054; and with a combined (scenario 3) are 611 days (42 days faster than normal time) and a decrease in cost to Rp540,525,412,830. The most economical alternative from this study is to use scenario 2 because it reduces the overall duration and cost reduction from the initial project cost budget plan of 653 days with a total cost of Rp540,607,665,070.

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