VOLUME 3 | NUMBER 2 | MARCH 2021
Available online at http://proceedings.worldconference.id.
ISSN: 2656-1174 (online)

Analysis of The Acceleration of Time and Cost of Construction Projects by Adding Labor and Working Hours (Overtime) using The Time Cost Trade Off Method (Case study: Construction of The Conexio Apartment Project)

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Abstrack

Systematic project management is needed to ensure the project implementation time is in accordance with the contract or even faster, so the cost incurred can provide benefits and also avoid the existence of fines due to delays in project completion. This study discusses the acceleration of time and cost project in the implementation of high rise building construction projects using the Time Cost Trade Off method. The author will analyze the scenario of accelerating the completion of the project by comparing the addition of working hours by 4 hours (scenario 1) and additional labor (scenario 2). The results of the analysis found the estimated time to accelerate the implementation of the project is from the normal duration of 600 calendar days, after a crash duration there is an acceleration of time to 582 calendar days. With a time efficiency of 18 days / 3.00%. The total cost due to acceleration of time (including indirect cost) for the addition of overtime hours for 4 hours (scenario 1) obtained a normal cost of IDR 66,637,746,719 (excl. VAT), then after the crash cost there is an increase in the cost to IDR 70,224,661,008 (excl. VAT) with an over cost of IDR 3,586,914,289 / 5.38%. Whereas with the addition of labor (scenario 2) a normal cost of IDR 66,637,746,719 (excl. VAT), then after the crash cost there is an increase in the cost to IDR 71,454,128,134 (excl. VAT) with an over cost of IDR 4,816,381,415 / 7.23%.

Keywords :
Crash Cost, Crash Duration, Project Acceleration, Time Cost Trade Off

1. Introduction

Time and cost greatly affect the success and failure of a project. Benchmarks for project success are usually seen from the short completion time at minimal cost without leaving the quality of the work. Systematic project management is needed to ensure that the project implementation time is in accordance with the contract or even faster, so that the cost incurred can provide benefits, and also avoid fines due to delays in project completion (Priyo, M., Sumanto, 2016).

This study discusses the acceleration of time and project cost in the implementation of the High Rise Building Project with the Time Cost Trade Off method. This method can be done by the method of implementing work by increasing the workforce, adding equipment or increasing work hours (overtime). To be able to achieve this, what must be done in order to accelerate time and cost is to create a project network, look for critical activities and calculate the duration of the project and know the number of resources.

In this case study, the project development experienced a work delay of -5.47% so that it would result in the postponement of completion of the completion of the Structural and Architectural work, while the target of the Owner was to hand over the Apartment Unit to consumers in July 2020 and to avoid contractor penalties due to late work. To find a solution to this, it is necessary to carry out an analysis of the acceleration of the implementation of the Structural work so that the project construction can be completed on time.

2. Stage of Problem Identification

In this case study project, it is known that per the end of August 2019 based on the weight of the S-curve, the work progress has a deviation of -5.47% from the cumulative plan of 36.99%. In addition, from the data obtained from the field, the workforce from the Formwork Sub-Construction has decreased greatly, with an average of 15 people in July 2019 and 12 people in August 2019, so that progress has decreased.

3. Scope and Limitation of the Problem

In general, the scope to be discussed in this study is as follows:

1. Time acceleration analysis using the Time Cost Trade Off method on projects that are experiencing delays.
2. Analysis of cost arising from the acceleration of the duration of the project so that direct and indirect cost can be found.

4. Analysis of Acceleration of Project Time and Cost

4.1 Accelerate Project Completion Time

There are four factors that can be optimized to carry out acceleration in an activity, which includes scheduling additional working hours (overtime), increasing the number of workers, using heavy equipment and changing construction methods in the field (Frederika, 2010).

1. Additional working hours (overtime)
   Overtime work can be done by increasing the hours worked every day with the same resources without increasing the workforce. The addition of working hours aims to increase production for one day so that the completion when adding work hours needs to pay attention to the length of time someone works so that it can cause that person's productivity to decrease due to being too tired. The reduced productivity value, especially for overtime work with the same human resources, can be seen in Figure 4.1.
2. Implementation of additional workforce
   The addition of manpower is intended as an increase in the number of workers in one work unit to carry out a certain activity without adding working hours. An optimum addition of labor will increase work productivity, but adding too much will actually reduce labor productivity due to various reasons, such as too little land to work and difficulty in supervision.

With the acceleration of this project there will be a reduction in the duration of activities. The total project cost is the sum of the direct cost and the indirect cost incurred by the project. The amount of the total cost depends on the length of the project implementation time. Both will change according to the time and progress of the project even though it cannot be calculated with a certain formula, but generally the longer the project runs, the higher the cumulative indirect cost required.

4.2 Time and Cost Relations

To determine the relationship between time and cost of an activity can be seen in Figure 4.2. Point A indicates normal conditions, while point B indicates accelerated conditions. The line connecting these points is called the time cost curve (soeharto, 1999)

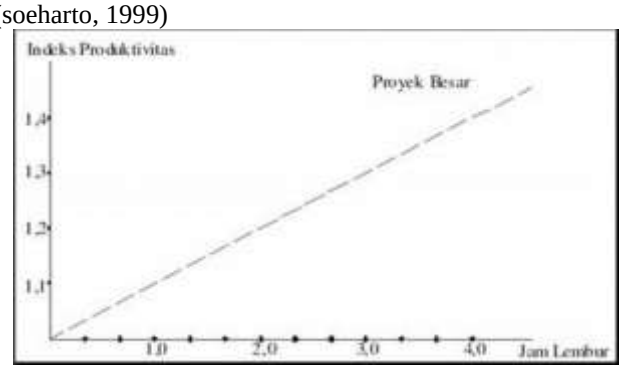

Figure 4.1 Graph of indication of decreased productivity due to overtime work

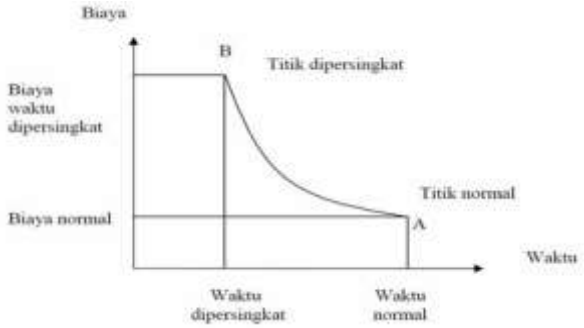

Figure 4.2 Normal and shortened time-cost relationship graph

There are two time values that will be shown by each activity in a network when there is an acceleration yaitu (ardika o p, 2014) :

1. Normal Duration
   The time needed to complete an activity or activities with existing normal resources without any additional cost in a project.
2. Crash Duration
   The time required by a project in its attempt to shorten the duration is shorter than normal duration.
   The acceleration process also causes changes in the cost elements, namely:

1. Normal Cost
   Cost incurred with the completion of the project in normal time. This cost estimate is at the time of planning and scheduling along with normal time determination.
2. Crash Cost
   The cost used to carry out the activity in a period is equal to the duration of its acceleration. This cost spurred work to be completed faster. The cost of the crash will be greater than the original cost, this is because the time is faster than normal.

In the end, the acceleration of the project duration can lead to an increase in direct cost that are used to increase the level of work productivity.

Definition of time cost trade off is a deliberate, systematic, and analytical process by testing all activities in a project that are focused on activities that are on a critical path. Next, do the compression starting from the critical path which has the lowest cost slope value. As for the formulation of the cost slope is as follows (Ervianto, 2004) :

$$\text{Cost Slope} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Duration} - \text{Crash Duration}}$$

5. Methodology and Work Stages

The stages in the analysis of the calculation of time and work cost are as follows:

5.1 Additional Overtime Hours (Scenario 1)

1. Calculate the coefficient of reduction in worker productivity

The normal working time for workers is 8 hours (starting at 08.00 and finishing at 17.00 with one hour of rest). In this alternative, this is done by providing an additional 4 hours of overtime work. The productivity reduction coefficient can be calculated using a graph indicating a decrease in productivity due to overtime working hours Figure 4.1. The calculation of the decrease in productivity due to overtime working for 4 hours is as follows:

Difference in productivity index = 1,4 – 1,3
= 0,1

Where can be calculated the difference in productivity index value is 0.1 in every hour. The calculation for overtime work for 4 hours is as follows:

Decreased work performance = 0,1 x 4 hours = 0,4/hours
Percentage reduction = 0,4 x 100% = 40%
The coefficient of reduced productivity due to overtime working for 4 hours:
= 100% - 40%
= 60% ~ 0,6

Furthermore, the coefficient of reducing productivity due to overtime working hours can be seen in the following table:

Table 1. The Coefficient of Reducing Productivity

Overtime Hours (hours)	Productivity Index Decrease	Decrease in Work Performance (/hour)	Percentage of Decreased Job Performance (%)	Productivity Reduction Coefficient
A	b	c = a x b	d = c x 100%	e = 100% - d
1	0.1	0.1	10%	0.9
2	0.1	0.2	20%	0.8
3	0.1	0.3	30%	0.7
4	0.1	0.4	40%	0.6

Source: Data Processing Results, 2020

2. Calculate daily productivity, with formulas:

$$\text{Daily Productivity} = \frac{Job\ Volume}{Job\ Duration}$$

The results of daily productivity calculations can be seen in the following table:

Job description	Unit	Lower Structural Work	Upper Structural Work
Concrete work	m3/day	11.39	22.30
Iron work	Kg/day	1,667.81	4,051.22
Formwork	m2/day	49.45	143.14

Source: Data Processing Results, 2020

3. Calculating hourly productivity, using the formula:

$$\text{Productivity / hour} = \frac{Daily\ productivity}{8\ hours}$$

The results of the calculation of hourly productivity can be seen in the following table :

Job description	Unit	Lower Structural Work	Upper Structural Work
Concrete work	m3/day	1.42	2.79
Iron work	Kg/day	208.48	506.40
Formwork	m2/day	6.18	17.89

Source: Data Processing Results, 2020

4. Calculate daily productivity after crash

In this calculation daily productivity is added to the results of labor productivity for 4 hours of overtime work, with the formula:

= (8 hours x prod. / hour) + (decreased work performance x prod. / hour)

The results of daily productivity calculations after the crash can be seen in the following table:

Job description	Unit	Lower Structural Work	Upper Structural Work
Concrete work	m3/day	11.96	23.41
Iron work	Kg/day	1,751.20	4,253.79
Formwork	m2/day	51.92	150.30

Source: Data Processing Results, 2020

5. Counting crash duration, with the formula:

$$\text{Crash duration} = \frac{Job\ Volume}{Daily\ Productivity\ After\ Crash}$$

The results of the calculation of crash duration can be seen in the following table:

Table 5. The Result of The Calculation of Crash Duration

Job description	Unit	Lower Structural Work	Upper Structural Work
Concrete work	Day	315	372
Iron work	Day	315	372
Formwork	Day	315	372

Source: Data Processing Results, 2020

So that the crash duration from the start of the structure work to the completion of the structural work if calculated based on the S-Curve schedule is as follows:

1. Preparation & Foundation Work = 120 day / 4 month
2. Soil work = 90 day / 3 month
3. Lower Structure Work to Upper Structure = 372 day / 12,4 month +
4. *Total crash duration* = *582 day / 19,4 month*

6. Calculate the total crash cost

Based on the decree of the Minister of Manpower and Transmigration of the Republic of Indonesia Number KEP.102/MEN/VI/2004 whereas the wages for additional work vary, for the addition of the first hour of work, the worker is paid 1.5 times the normal hourly wage and for the next additional work hour the worker gets 2 times the normal hourly wage.

The calculation of cost due to additional overtime working hours can be formulated as follows:

1. Normal wages of workers daily,
   = Productivity daily x Unit price for workers' wages
2. Normal wages of workers / hour,
   = Productivity / hour x Unit price for workers' wages
3. Overtime fee of 4 hours (1 day),
   = (1,5 x Normal hourly wages (first hour of overtime work)) + (2n x Normal hourly wages (for the next hour of overtime))
   *) n = Additional working hours

The results of calculating the cost of overtime working 4 hours (1 day) can be seen in the following table:

Table 6. The results of calculating the cost of overtime working 4 hours

a. Lower Structural Work

NO	Job description	Unit	Normal hourly wages (IDR/ hour)	First hour of overtime work (IDR/1 hour)	For the next hour of overtime (IDR/3hour)	Overtime fee of 4 hours (IDR)
1	Concete work					
	-Wages for installing a concrete stop	m3	7,119.73	10,679.59	42,718.37	53,397.97
	-Concrate curing waages	m3	22,783.13	34,174.70	136,698.80	170,873.50
	-Wages for cast concrete with a pump	m3	46,990.21	70,485.32	281,941.27	352,426.59
2	Iron Work					
	-Wages lower iron	kg	5,211.89	7,81.84	31,271.37	39,089.21
	-Wages for installing iron	kg	187,628.21	281,442.31	1,125,769.25	1,407,221.56
3	Form work					
	-Wages for installing formwork	m2	219,546.66	329,319.99	1,317,279.96	1,646,599.95

Source: Data Processing Results, 2020

Table 7. The results of calculating the cost of overtime working

b. Upper Structural Work

NO	Job description	Unit	Normal hourly wages (IDR/ hour)	First hour of overtime work (IDR/1 hour)	For the next hour of overtime (IDR/3hour)	Overtime fee of 4 hours (IDR)
1	Concete work					
	-Wages for installing a concrete stop	m3	13,935.02	20,902.52	83,610.10	104,512.62
	-Concrate curing waages	m3	44,592.05	66,888.08	267,552.31	334,440.38
	-Wages for cast concrete with a pump	m3	91,971.11	137,956.66	551,826.63	689,783.29
2	Iron Work					
	-Wages lower iron	kg	12,660.07	18,990.11	75,960.45	94,950.56
	-Wages for installing iron	kg	455,762.69	683,644.03	2,734,576.13	3,418,220.16
3	Form work					
	-Wages for installing formwork	m2	635,558.61	953,337.92	3,813,351.68	7,766,689.60

Source: Data Processing Results, 2020

4. Crash Cost of workers wages daily
   = Normal wages of workers /day + Worker's overtime cost /day
   The results of the calculation of the Crash Cost of workers wages per day can be seen in the following table:

Table 8. The results of calculating the cost of overtime working

a. Lower Structural Work

NO	Job description	Unit	Normal hourly wages (IDR/ hour)	Overtime fee of 4 hours (IDR)	Crash cost of workers' wages (IDR/day)
1	Concete work				
	-Wages for installing a concrete stop	m3	56,957.83	53,397.97	110,355.80
	-Concrate curing waages	m3	182,265.06	170,873.50	353,138.56
	-Wages for cast concrete with a pump	m3	375,921.69	352,426.59	728,348.28
2	Iron Work				
	-Wages lower iron	kg	41,695.16	39,089.21	80,784.37
	-Wages for installing iron	kg	1,5011,025.67	1,407,211.56	2,908,237.23
3	Form work				
	-Wages for installing formwork	m2	1,756,373.28	1,646,599.95	3,402,973.23

Source: Data Processing Results, 2020

Table 9. The results of calculating the cost of overtime working

b. Upper Structural Work

NO	Job description	Unit	Normal hourly wages (IDR/ hour)	Overtime fee of 4 hours (IDR)	Crash cost of workers' wages (IDR/day)
1	Concete work				
	-Wages for installing a concrete stop	m3	111,480.13	104,512.62	215,992.75
	-Concrate curing waages	m3	356,736.41	334,440.38	691,176.79
	-Wages for cast concrete with a pump	m3	735,768.84	689,783.29	1,425,552.13
2	Iron Work				
	-Wages lower iron	kg	101,280.60	94,950.56	196,231.16
	-Wages for installing iron	kg	3,646,101.50	3,418,220.16	7,064,321.67
3	Form work				
	-Wages for installing formwork	m2	5,084,468.90	4,766,689.60	9,851,158.50

Source: Data Processing Results, 2020

5. Total crash cost
   = Crash Cost of workers wages /day x Crash Duration
   The results of the total crash cost calculation can be seen in the following table:

Table 10. The results of calculating the cost of overtime working

a. Lower Structural Work

No	Job desciption	Unit	Crash cost of worker's wages (IDR/day)	Crash duration (day)	Total wagr crash cost (IDR)
1	Concrete work				
	-Wages for installing concrete stop	m3	110,355.80	315.00	34,762,076.92
	-Cocrete curing wages	m3	353,138.56	315.00	111,238646.15
	-Wages for cast concrete with a pump	m3	728,348.28	315.00	229,429.707.68
2	Iron work				
	-Wages Lower iron	Kg	80,784.37	315.00	25,447,705.75
	-Wages for installing iron	Kg	2,908,237.23	315.00	916,094,726.91
3	Form work				
	-Wages for installing formwork	m2	3,402,973.23	315.00	1,071,936,568.36
				Total crosh	2,388,908,801.76

Source: Data Processing Results, 2020

For material and subcontractor cost for earthworks and foundations (A) IDR 11,651,727,571 as well as lower structure works (B) IDR 10,649,939,567 determined based on the normal price obtained from the contractor. So that the total crash cost for substructure and foundation work are as follows:

= The total crash cost of lower structure wages + (A) + (B)
= IDR 2,388,908,801 + IDR 11,651,727,571 + IDR 10,649,939,567
= IDR 24,690,575,940

Table 11. The results of calculating the cost of overtime working 4 hours

b. Upper Structural Work

No	Job desciption	Unit	Crash cost of worker's wages (IDR/day)	Crash duration (day)	Total wagr crash cost (IDR)
1	Concrete work				
	-Wages for installing concrete stop	m3	215,992.75	372.00	80,349,301.91
	-Cocrete curing wages	m3	691,176.79	372.00	257,117,766.10
	-Wages for cast concrete with a pump	m3	1,425,552.13	372.00	530,305.392.59
2	Iron work				
	-Wages Lower iron	Kg	196,231.16	372.00	72,997,990.55
	-Wages for installing iron	Kg	7,064,321.67	372.00	916,094,726.91
3	Form work				
	-Wages for installing formwork	m2	9,851,158.50	372.00	3,664,630,960.98
				Total crosh	7,233,329,071.85

Source: Data Processing Results, 2020

For the cost of materials and subcontractors for the upper structure work (C) IDR 26,601,344,562 determined based on the normal price obtained from the contractor. So that the total crash cost for superstructure work is as follows:

= *The total crash cost of upper structure wages + (C)*
= IDR 7,233,329,071 + IDR 26,601,344,562
= IDR 33,834,673,634

6. Calculation of indirect cost in the addition of overtime working hours

For the calculation of indirect cost, the unit price is obtained from the contractor, so that the calculation of the Crash cost at the Indirect Cost cost can be formulated as follows:

= *Duration after crash (month) x Unit Price*

The results of the calculation of indirect cost can be seen in the following table:

Table 12.. The results of the calculation of indirect cost s

No	Job description	Unit	Volume normal duration (month) a	Volume crash duration (month) b	Unite price / month (IDR) c	Total (IDR) D = b x c
1	General/ / overhead cost					
	Staff salary cost	Month	20.00	19.40	189,422,500	3,674,769,500
	Operating cost	Month	20.00	19.40	28,934,050	561,320,570
	Project office cost	Month	20.00	19.40	36,288,500	703,996,900
	Overhead cost	Month	20.00	19.40	7,452,750	144,583,350
	Kitchen cost	Month	20.00	19.40	26,198,095	508,243,044
2	Tool cost					
	Tower crane	Month	20.00	19.40	63,590,00	1,272,446,000
	Pessenger holst	Month	5.00	4.40	44,000,000	193,600,000
	Concrete pump etc.	Month	7.00	6.40	93,400,000	597,892,034
	PLN electricity cost	Month	20.00	19.40	49,633,610	962,892,034
	Rent a survey tool	Month	20.00	19.40	2,612,500	50,682,500
	Rent iron fabrication tools	Month	20.00	19.40	7,050,000	136,770,000
	Rent a compressor	Month	7.00	6.40	9,914,286	63,451,429
	Rent a vibrator	Month	7.00	6.40	21,142,857	135,314,286
	Genset cost 150 KVA	Month	1.00	1.00	182,170,000	182,170,000
	Work ald cost	Month	20.00	19.40	11,550,000	224,070,000
3	Cost of facilliaties – Project infrastrustur					
	Project office creation	Month	1.00	1.00	887,928,800	887,928,800
	K3 equipment	Month	20.00	19.40	17,416,566	337,881,379
	Rent a scaffolding	Month	20.00	19.40	6,005,836	116,513,210
	Electricity & water cost	Month	20.00	19.40	43,001,008	834,219,552
	Backup cleaning cost	Month	20.00	19.40	5,709,891	110,771,880
					Total	11,669,411,433

Source: Data Processing Results, 2020

So that the total Crash cost value due to the addition of 4 hours of work (Scenario 1) is as follows:

Crash cost of substructure and foundation work = IDR 24,690,575,940
Crash cost of upper structure work = IDR 33,834,673,634
Crash cost for indirect cost = IDR 11,699,411,433 +
Total Cost (Excl. VAT) = IDR 70,224,661,008

7. Calculating the cost slope, using the formula:

$$\text{Cost Slope} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Duration} - \text{Crash Duration}}$$

$$= \frac{70{,}224{,}661{,}008 - 66{,}637{,}746{,}719}{600 \text{ day } (20 \text{ month}) - 582 \text{ day } (19.4 \text{ month})}$$

$$= \text{IDR } 199{,}273{,}016$$

5.2 Additional Workforce (Scenario 2)

Another strategy taken to accelerate the project duration is by increasing the number of workers. The coefficient of labor uses the SNI coefficient with the duration of the work using the results of the crash duration calculation in Scenario 1, so that it can be compared with the same amount of duration between the two scenarios. The steps for crashing the program in scenario 2 are as follows:

1. Calculate the number of workers and the cost of wages of workers

The labor coefficient on Concrete, Ironing and Formwork can be seen in the table below:

Table 13. The labor coefficient on Concrete, Ironing and Formwork

No	Job description	Unit	Labor Coefficient			Labor Unit Price		
			Concrete work (1m3)	Iron work (1kg)	Formwork (1m2)	Concrete work (IDR)	Iron work (IDR)	Formwork (IDR)
1	Workers	Oh	1.323	0.007	0.660	75,000.00	75,000.00	75,000.00
2	Repairman	Oh	0.189	0.007	0.330	85,000.00	90,000.00	90,000.00
3	Foreman	Oh	0.019	0.001	0.033	90,000.00	100,000.00	100,000.00
4	Foreman	Oh	0.132	0.000	0.033	100,000.00	100,000.00	100,000.00

Source: SNI

For the calculation of the amount of labor and wage cost using the following formula:

$$\textit{Total manpower} = \frac{\textit{Labor Coefficient x Volume}}{\textit{Job Duration}}$$

$$\textit{Labor Wages} = \textit{Total manpower x Unit wage price}$$

The results of the calculation of the number of workers and the cost of wages can be seen in the following table:

Table 14. The results of the calculation of the number of workers and the cost of wages

a. Lower structure work

Description	Concrete work		Iron work		Formwork	
	Total manpower	Total wages IDR/day	Total wages	Total wages IDR/day	Total wages	Total wages IDR/day
Wokers	16	1,200,000	13	975,000	35	2,625,000
Repairman	3	255,000	13	1,170,000	18	1,620,000
Foreman	1	90,000	2	200,000	2	200,000
Foreman	2	200,000	1	100,000	2	200,000
Total wages		1,745,000		2,445,000		4,645,000

Source: Data Processing Results, 2020

So the total wage cost for concrete work, ironing and formwork for the substructure are as follows:
= (Wages Concrete work + Wages Iron work + Wages Formwork) x Duration (day)
= (1,745,000 + 2,445,000 + 4,645,000) x 315 day
= IDR 2,783,025,000

Table 15. The results of the calculation of the number of workers and the cost of wages

b. Upper structure work

Description	Concrete work		Iron work		Formwork	
	Total manpower	Total wages IDR/day	Total wages	Total wages IDR/day	Total wages	Total wages IDR/day
Wokers	31	2,325,000	30	2,250,000	100	7,500,000
Repairman	5	455,000	30	2,700,000	50	4,500,000
Foreman	1	90,000	3	300,000	5	500,000
Foreman	4	400,000	2	200,000	5	500,000
Total wages		3,240,000		5,450,000		13,000,000

Source: Data Processing Results, 2020

So the total wage cost for concrete work, ironing and formwork on the upper structure are as follows:
= (Wages Concrete work + Wages Iron work + Wages Formwork) x Duration (day)
= (3,240,000 + 5,450,000 + 13,000,000) x 372 day
= IDR 8,068,680,000

2. Calculate the total crash cost

a. Lower structure work

For material and subcontractor cost for earthworks and foundations (A) IDR 11,651,727,571 as well as lower structure works (B) IDR 10,649,939,567 determined based on the normal price obtained from the contractor. So that the total crash cost for substructure and foundation work are as follows:

= Total crash cost of lower structure wages + (A) + (B)
= IDR 2,783,025,000 + IDR 11,651,727,571 + IDR 10,649,939,567
= IDR 25,084,692,138

b. Upper structure work

For the cost of materials and subcontractors for the upper structure work (C) IDR 26,601,344,562 determined based on the normal price obtained from the contractor. So that the total crash cost for superstructure work is as follows:

= Total crash cost of upper structure wages + (C)
= IDR 8,068,680,000 + IDR 26,601,344,562
= IDR 34,670,024,562

he calculation of the unit price indirect cost is obtained from the contractor, so the calculation of the Crash cost at the Indirect Cost can be seen in the table in point F. So that the total Crash cost value due to the addition of labor (Scenario 2) is as follows:

Crash cost of substructure and foundation work	= IDR 25,084,692,138
Crash cost of upper structure work	= IDR 34,670,024,562
Crash cost for indirect cost	= IDR 11,699,411,433 +
Total Cost (Excl. VAT)	= IDR 71,454,128,134

3. Calculating the cost slope, using the formula:

$$\text{Cost Slope} = \frac{Crash\ Cost - Normal\ Cost}{Normal\ Duration - Crash\ Duration}$$

$$= \frac{71{,}454{,}128{,}134 - 66{,}637{,}746{,}719}{600\ day\ (20\ month) - 582\ day\ (19{,}4\ month)}$$

= IDR 267,576,745

5.3 Total Cost Graph

After the crashing program, results are obtained as shown above, then to make it easier to understand the results of the analysis that has been done it can be presented in the form of a recapitulation table and graph as below:

Table 16. Table recapitulation of analysis results

No	Method Analysis	Normal Duration (day)	Crash Duration (day)	Normal Cost (IDR)	Crash Cost (IDR)	Time efficiency	Cost Efficiency	Research Result
	Additional 4 Hours of Overtime Work (Scenario 1)	600	582	66,637,746,719	70,224,661,009	3.00%	-5.38%	- Normal Duration: 600 day --> Crash Duration: 582 day; - Normal Cost: 66,637,746,719 --> Crash Cost: 70,224,661,008; - Time efficiency: 3.00%; - Cost Efficiency: -5.38%
	Additional Workforce (Scenario 2)	600	582	66,637,746,719	71,454,128,135	3.00%	-7.23%	- Normal Duration: 600 day --> Crash Duration: 582 day; - Normal Cost: 66,637,746,719 --> Crash Cost: 71,454,128,134; - Time efficiency: 3.00%; - Cost Efficiency: -7.23%

Source: Data Processing Results, 2020

Total cost graph

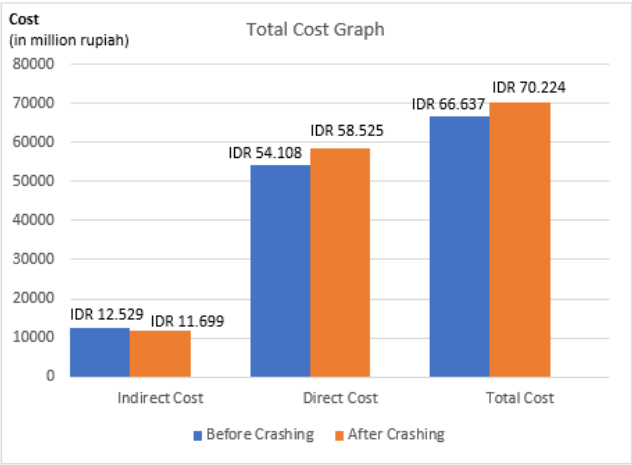

Figure 3. Total cost graph(scenario 1)

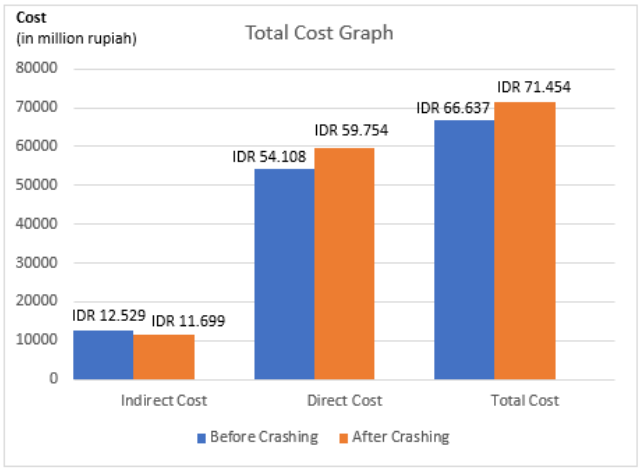

Figure 4. Total cost graph (scenario 2)

5.4 Implementation of Time Cost Trade Off (TCTO)

After analyzing the resulting total cost graph. The total project cost is the sum of the direct cost with the indirect cost incurred after the duration compression process, the direct cost will increase while the indirect cost will decrease because the duration is faster than before. The analysis results are compared with the project schedule and cost before being accelerated. On the curve, point A shows normal conditions, while point B shows accelerated conditions. The line connecting these points is called a time-cost curve. To find out the relationship between the time and cost of adding 4 hours of overtime work (scenario 1) and additional workforce (scenario 2) it can be seen in the curve below:

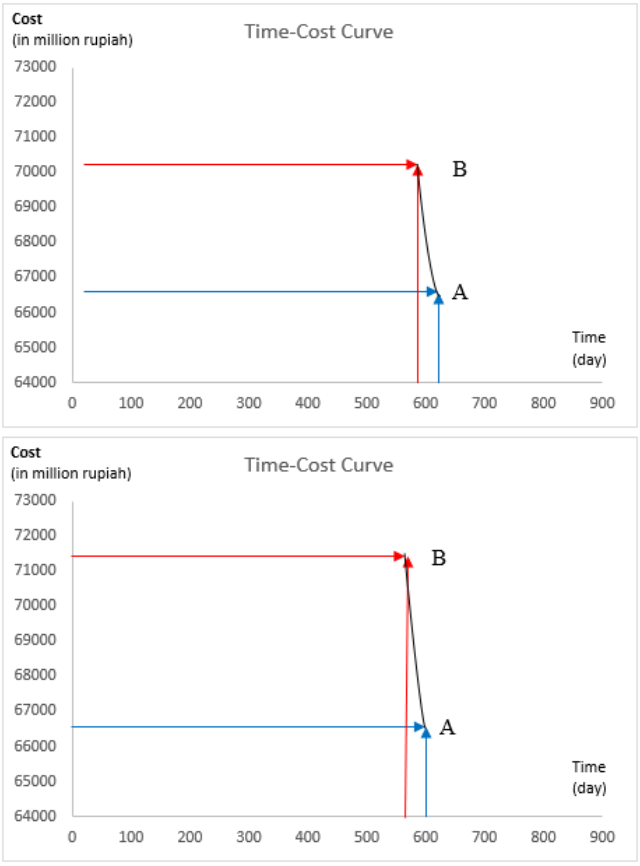

Figure 6. Time-cost curve (scenario 1), Time-cost curve (scenario 2)

6. Conclusions and Suggestions

6.1 Conclusion

a. Estimated Acceleration of Work Time

The results of the above analysis show that the estimated time for the acceleration of project implementation is from the normal duration of 600 calendar days, then after the crash duration is carried out there is an acceleration of the time to 582 calendar days. With a time efficiency of 18 days / 3.00%.

The total cost due to time acceleration (including indirect cost) are as follows:

1. Additional 4 Hours of Overtime Work (Scenario 1)
   Dari *normal cost* sebesar IDR 66,637,746,719 (excl. VAT), kemudian setelah *crash cost* terdapat kenaikan biaya menjadi IDR 70,224,661,008 (excl. VAT). Dengan *over cost* sebesar IDR 3,586,914,289 / 5.38 %.
   Cost slope sebesar IDR 199,273,016
2. Additional Workforce (Scenario 2
   From the normal cost of IDR 66,637,746,719 (excl. VAT), then after the crash cost there was an increase in cost to IDR 71,454,128,134 (excl. VAT). With an over cost of IDR 4,816,381,415 / 7.23%.
   Cost slope of IDR 267,576,745

6.2 Suggestions

a. In the case of delays caused by man (human) factors, the selection of the method of adding overtime working hours is more effective and efficient in the case study above, because the increase in cost is less than the method of adding labor.
b. This research is carried out on building construction, therefore further research is expected to be carried out on road, bridge, dam or other civil projects.

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