Time Cost Trade Off Analysis on the Training Center Project PT. X With Additional Working Hours

Anjas Handayani dan Dodi Khoerul
Faculty of Engineering, Mercu Buana University Jakarta, Indonesia

anjas.handayani@gmail.com, khoeruldodi@gmail.com

Abstract

In the world of construction the most common problem is delays in project implementation. To overcome this problem, several alternatives for project acceleration are used, such as additional overtime hours, additional workforce, changes in working methods that are faster, use of materials with faster installation, and use of more productive heavy equipment. The object of this research is the PT. X. Acceleration is carried out using the time cost trade off method with the addition of overtime working hours on structural work that is on the critical path. The purpose of this study is to determine the level of increase in project costs due to overtime activity and time acceleration generated by using this method. The results of cost calculations by accelerating through additional working hours obtained the shortest project duration, namely for 112 days from the total project completion plan for 150 working days with an increase in costs of Rp. 53,967,111.00 so that the total cost becomes Rp. 8,813,167,113. Or 0.62% more expensive than the planned budget under normal conditions, namely Rp. 8,759,200,000.00. From the results of these studies, it can be concluded that the addition of overtime working hours can accelerate the project duration and increase the total project budget costs that must be spent. 62% more expensive than the planned budget under normal conditions, namely Rp. 8,759,200,000.00. From the results of these studies, it can be concluded that the addition of overtime working hours can accelerate the project duration and increase the total project budget costs that must be spent.

Keywords:
Overtime Hours, Project Acceleration, Time Cost Trade Off.

1. Introduction

Improving the quality of human resources in an institution or institution cannot be separated from the role of a training center in it. Training is a series of individual activities in systematically increasing skills and knowledge so that they are able to have professional performance in their fields (Sri Widodo, 2016). The objectives of the training carried out by the company are to increase productivity, improve quality, support HR planning, increase member morale, provide indirect compensation, improve occupational health and safety, prevent expiration of personnel skills and knowledge, increase the development of personnel capabilities and expertise (Sri Widodo, 2016). A project is considered successful if the work is completed in a time that is according to plan and can benefit human resources effectively and efficiently as well as fund control that is maintained at least (Putra, 2018). Therefore, careful planning before completion of a project needs to be well planned in order to reduce the risks of obstacles that will occur. There are so many ways that are used in planning or controlling the time and cost of a project, one of which is the time cost trade off method, which provides an alternative for project planners to be able to make the best planning so that they can optimize time and costs. complete a project, and streamline the required resources with the most optimum cost increments. The main focus of this time cost trade off method is project activities that are on a critical trajectory with the addition of existing alternatives so that activities that are on a critical path can be completed on time. Acceleration can be done by increasing work hours, increasing the number of workers, using more productive tools and using faster work methods.

The Training Center building construction project is scheduled to be completed for 5 months starting from July 14 2020 - December 14 2020 and experiences delays in the 4th week of -1.596% of the planned schedule of 3.562%. The slowdown occurred due to unfulfilled licensing conditions for the area, so the project had to experience a temporary suspension. In addition, the slowdown also occurred due to the damage to the bore pile machine so that drilling was carried out temporarily manually. To achieve the target according to plan, the contractor accelerates using the time cost trade off method with additional working hours.
2. Research methodology

2.1. General Description

The method used in this research is quantitative research method which can be interpreted as a research method based on the positivism philosophy, used to research on certain populations or samples, data collection using research instruments, data analysis is quantitative / statistical, with the aim of testing hypotheses that are has been determined (Sugiyono, 2019).

2.2. Precedent Diagram Method (PDM)

In PDM, arrows only act as a link or provide information on the relationship between activities, and do not unify activity periods as in the CPM. Constraint shows the relationship between activities with a line from the previous node to the next node. Because each node has two ends, namely the beginning or ending = (S) and the ending or ending = (F), there are 4 types of constraints, namely beginning to beginning (SS), beginning to ending (SF), ending to ending (FF) and end to beginning (FS). On the constraint line an explanation of the lead or lag time is needed. In the precedence diagramming method, activities or activities are indicated by nodes that are square and large in size. Inside this node contains the following:

- Duration
- Activity or activity number
- Activity description
- ES, EF, LS, LF
- The float that happened

2.3. Calculation of Normal Costs (Normal Cost)

Normal cost is the total cost of each work activity, which consists of the cost of wages and materials contained in the project cost budget plan. Normal cost is divided into two parts, namely normal cost for materials and normal cost for materials. Here is the formula for calculating the material coefficient and the wage coefficient:

\[
\frac{\text{Material coefficient}}{\text{Direct cost weight}} = \frac{\text{material cost}}{\text{material cost} + \text{labour cost}}
\]

\[
\frac{\text{Indirect costs weight}}{\text{Labour coefficient}} = \frac{\text{100\% - 91\%}}{\text{material cost} + \text{labour cost}}
\]

2.4. Labor Needs Analysis

Before accelerating, it must first analyze the number of workers required during normal working hours based on the coefficient value for each of these jobs using Ms. Excel 2016. Here is the formula for calculating labor requirements:

\[
\text{Number of workers required} = \text{volume} \times \text{coefficient} = \text{wage price for work} = \text{number of workers} \times \text{wages of workers} = \frac{1}{\text{labour productivity}} = \frac{\text{labour productivity} \times \text{work duration}}{\text{Total of workers per day}} = \frac{\text{labour productivity} \times \text{work duration}}{\text{Volume}}
\]

2.5. Calculation of Worker Wages for Overtime Hours

The method of calculating the price of workers' wages for overtime according to the Decree of the Minister of Manpower Number KEP. 102 / MEN / VI / 2004 Concerning Overtime Time and Article 11 Overtime Wages, which were previously regulated in Article 8, are calculated as follows:

10. The calculation of overtime pay is based on the monthly wage

The method of counting an hour is 1173 times a month's wages

Formula:

11. Increase in overtime pay to 1 = 1.5 x 1 / (173) x normal wages x work days a month

12. Additional wages for overtime hours to 2 etc. = 2 x 1 / (173) x normal wages x work days a month
From Figure 1 above, it can be described as follows:

Overtime fee per day = (first hour of overtime x 1.5 x normal hour's wages) + (next hour of overtime x 2 x normal hour's wages) ……………………………………………………………. (1)

Daily productivity = \( \frac{\text{volume}}{\text{normal duration}} \) ……………………………………………………… (2)

Productivity per hour = \( \frac{\text{8 hours}}{\text{day productivity}} \) ……………………………………………………… (3)

Daily productivity due to overtime work = (axbx prod per hour) ……………………………………… (4)

by:

a = The number of additional hours worked overtime,

b = Coefficient of decrease in worker productivity due to additional overtime hours.

Daily productivity after a crash = (8 hours x prod. Every hour) + (axbx prod. Every hour) ……………………………………… (5)

a = The number of additional hours worked overtime,

b = Coefficient of decreasing productivity of overtime work

Crash duration = \( \frac{\text{prod. harian sesudah crash}}{\text{crash}} \) ……………………………………………………… (6)

Normal cost hourly workers = price of labor x product per hour ……………………………………… (7)

Normal cost workers per day = 8 hours x normal cost per hour ……………………………………… (8)

Normal cost = normal duration x normal cost of workers per day ……………………………………… (9)

Crash cost = normal cost of workers per day + cost of overtime per day ……………………………………… (10)

Crash cost = crash duration x crash cost of workers per day ……………………………………… (11)

Cost slope = ……………………………………………………………………………………………….. (12)

3. Results and Analysis

3.1. Determination of the Critical Path

In this study, to determine the duration of each work, it can be seen from the project plan schedule that has been made previously. After knowing the duration of each activity, then connecting each activity using the Ms. Project 2016 application, it will be known that activities that are on the critical path are marked in red on the name of their job or on the bar chart and network diagram as in Figure 1.
3.2. Calculation of Normal Costs (Normal Cost)

3.2.1. Material Coefficient Calculation

The following is an example of calculating material coefficients for temporary facility office and toilet work:

- Job volume: 21 m²
- Material cost: Rp. 1,027,624.60 (obtained from the price of materials multiplied by the project AHS coefficient)
- Wage Costs: Rp. 413,750.00 (obtained from the wage price multiplied by the project AHS coefficient)
- Material costs and wages: Rp. 1,441,374.60 (obtained from the sum of material costs and wages)
- HSP Value: Rp. 1,585,512.06 (obtained from the cost of materials and wages added by overhead costs and profit 10%)

Material coefficient = \( \frac{\text{Material cost}}{\text{material cost & labour cost}} \) = \( \frac{\text{Rp. 1,027,624.60}}{\text{Rp. 1,441,374.60}} \) = 0.713

3.2.2. Wage Coefficient Calculation

The following is an example of calculating the wage coefficient for temporary facility office and toilet work:

Wage Coefficient = \( \frac{\text{labor cost}}{\text{material cost & labour cost}} \) = \( \frac{\text{Rp. 413,750.00}}{\text{Rp. 1,441,374.60}} \) = 0.287

Figure 2. Critical Path Analysis at Ms. Project
Source: Author's Process, 2020
3.2.3. Normal material cost calculation
The total normal cost of materials for the Temporary Facility Office, Toilet work:

\[ \text{Total Normal Cost} = \text{Koef. Materials} \times \text{material costs and wages} \times \text{volume of work} \]

\[ = 0.713 \times \text{Rp. 1,441,374.60} \times 21 \text{ m}^2 \]

\[ = \text{Rp. 21,581,701.89} \]

3.2.4. Normal wage cost calculation
Total normal cost of wages for Temporary Facility Office, Toilet jobs:

\[ \text{Total Normal Cost} = \text{Koef. wages} \times \text{material costs and wages} \times \text{volume of work} \]

\[ = 0.287 \times \text{Rp. 1,441,374.60} \times 21 \text{ m}^2 \]

\[ = \text{Rp. 8,687,164.71} \]

3.3. Labor Needs Analysis
The next step is to make an analysis of labor requirements for jobs that are on the critical path and then the project acceleration will be carried out on these jobs.

The following is an example of an analysis of labor requirements at work Temporary Facility Office, Toilet:

3.3.1. Required data
- Job volume: 21 m²
- Duration of work: 7 days

<table>
<thead>
<tr>
<th>Number</th>
<th>Labor</th>
<th>Coefficient</th>
<th>Labor Cost (A)</th>
<th>Total Labor (B) = Coef. x Volume</th>
<th>Total Cost (C) = (A) * (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Workers</td>
<td>2</td>
<td>Rp. 70,000.00</td>
<td>42.00</td>
<td>Rp. 2,940,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Bricklayer</td>
<td>1</td>
<td>Rp. 80,000.00</td>
<td>21.00</td>
<td>Rp. 1,680,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Carpenter</td>
<td>2</td>
<td>Rp. 80,000.00</td>
<td>42.00</td>
<td>Rp. 3,360,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Foreman</td>
<td>0.3</td>
<td>Rp. 95,000.00</td>
<td>6.00</td>
<td>Rp. 570,000.00</td>
</tr>
<tr>
<td>5</td>
<td>Labour Supervision</td>
<td>0.05</td>
<td>Rp. 105,000.00</td>
<td>1.00</td>
<td>Rp. 105,000.00</td>
</tr>
</tbody>
</table>

3.4. Determining Labor Productivity Per Day
To find the number of workers required per day, the coefficient value of the labor is needed. Labor productivity can be found using the formula:

\[
\text{Labor productivity} = \frac{1}{\text{labour coefficient}}
\]

3.4.1. Example of labor productivity per day in temporary facility office & toilet work
- Volume: 21 m²
- Duration: 7 days
- Labor coefficient:
  - Workers = 2
  - Bricklayer = 1
  - Carpenter = 2
  - Foreman = 0.3
  - Labour supervision = 0.05

(Coefficient value obtained from AHS project)
- Workers: \[\frac{1}{2.00} = 0.50 \text{ m}^2 / \text{day}\]
- Bricklayer: \[\frac{1}{1.00} = 1.00 \text{ m}^2 / \text{day}\]
- Carpenter: \[\frac{1}{2.00} = 0.50 \text{ m}^2 / \text{day}\]
- Foreman: \[\frac{1}{0.30} = 3.33 \text{ m} / \text{day}\]
- Labour supervision: \[\frac{1}{0.05} = 20.00 \text{ m} / \text{day}\]

3.5. Determine Total Labour Per Day
The next step is to determine the number of workers needed for each work that is passed the critical path before accelerating the project using the overtime system. The number of workers per day can be found using the formula:

\[
\text{Number of workers per day} = \frac{\text{volume}}{\text{labour productivity} \times \text{work duration}}
\]
3.6. Calculating Labour Cost Per Day

The next step is to calculate the wages per day of labor for normal work or before the acceleration of the project is carried out, namely the following formula:

\[ \text{Wage price} = \text{Number of workers per day} \times \text{Unit price of labor} \]

3.6.1. Example of wages per day for temporary office facility & toilet work

<table>
<thead>
<tr>
<th>Labor</th>
<th>Number</th>
<th>Rate</th>
<th>Wage price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>6</td>
<td>Rp. 70,000.00</td>
<td>Rp. 420,000.00</td>
</tr>
<tr>
<td>Bricklayer</td>
<td>3</td>
<td>Rp. 80,000.00</td>
<td>Rp. 240,000.00</td>
</tr>
<tr>
<td>Carpenter</td>
<td>6</td>
<td>Rp. 80,000.00</td>
<td>Rp. 480,000.00</td>
</tr>
<tr>
<td>Foreman</td>
<td>0.90</td>
<td>Rp. 95,000.00</td>
<td>Rp. 85,500.00</td>
</tr>
<tr>
<td>Foreman</td>
<td>0.15</td>
<td>Rp. 105,000.00</td>
<td>Rp. 15,750.00</td>
</tr>
</tbody>
</table>

3.7. Analysis of the Acceleration of Project Completion Duration

In this research, the project acceleration process will be carried out by adding 4 hours of work so that it can be seen the difference in duration between before acceleration and after acceleration. In addition, it can also be seen the difference in costs that must be incurred to complete the project after accelerating the project.

3.7.1. Determining labor productivity after adding four hours of work to the project used working hours per day is 8 hours / day.

Then you can find the productivity per hour using the formula:

\[ \text{Labor productivity} = \frac{\text{labour productivity per day}}{\text{normal work duration}} \]

Productivity of overtime labor = \(\frac{(\text{cap./day} + (\text{ovt. hours} \times \text{cap./hours*koef.}))}{\text{ovt. hours}}\)

Normal duration of work = 8 hours

Duration of overtime work = 4 hours

Total hours worked = 12 hours

3.7.2. Determines the duration after adding four hours of overtime

After getting the labor productivity value during overtime, then you can find work after being accelerated. The formula used is as follows:

\[ \text{Duration of work crashing} = \frac{\text{volume}}{\text{work productivity} \times \text{12 jam x total labour}} \]

<table>
<thead>
<tr>
<th>Number</th>
<th>Labor</th>
<th>Total Labor / day</th>
<th>Productivity / day M2 / day</th>
<th>Crash duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Workers</td>
<td>6</td>
<td>0.69</td>
<td>5.00</td>
</tr>
<tr>
<td>2</td>
<td>Bricklayer</td>
<td>3</td>
<td>1.38</td>
<td>5.00</td>
</tr>
<tr>
<td>3</td>
<td>Carpenter</td>
<td>6</td>
<td>0.69</td>
<td>5.00</td>
</tr>
<tr>
<td>4</td>
<td>Foreman</td>
<td>0.9</td>
<td>4.58</td>
<td>5.00</td>
</tr>
<tr>
<td>5</td>
<td>Labour Supervision</td>
<td>0.15</td>
<td>27.5</td>
<td>5.00</td>
</tr>
</tbody>
</table>

3.7.3. Determine additional costs and total labor wages

The next step is to calculate additional costs due to the addition of four hours of overtime per day using a formula based on the written provisions in the Minister of Manpower Decree Number KEP.102 / MEN / VI / 2004 article 11 regarding overtime wages. The formula is as follows:

13. \[ \text{Increase in overtime pay to } = 1.5 \times \text{normal wages x work days a month} \times \frac{1}{173} \]

Addition of the 2nd overtime pay and so on = \[ 2 \times \text{normal wages x work days a month} \times \frac{1}{173} \]

Calculation data:
Table 3. Total Overtime Cost

<table>
<thead>
<tr>
<th>Number</th>
<th>Labour</th>
<th>Labor Cost (A)</th>
<th>Overtime Cost (the first hour)</th>
<th>Overtime Cost (The next 3 Hours)</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Workers</td>
<td>Rp. 70,000.00</td>
<td>Rp. 14,566.47</td>
<td>Rp. 58,265.90</td>
<td>Rp. 142,832.37</td>
</tr>
<tr>
<td>2</td>
<td>Iron Worker</td>
<td>Rp. 85,000.00</td>
<td>Rp. 17,687.86</td>
<td>Rp. 70,751.45</td>
<td>Rp. 173,439.31</td>
</tr>
<tr>
<td>3</td>
<td>Bricklayer</td>
<td>Rp. 80,000.00</td>
<td>Rp. 16,647.40</td>
<td>Rp. 66,589.60</td>
<td>Rp. 163,237.00</td>
</tr>
<tr>
<td>4</td>
<td>Carpenter</td>
<td>Rp. 80,000.00</td>
<td>Rp. 16,647.40</td>
<td>Rp. 66,589.60</td>
<td>Rp. 163,237.00</td>
</tr>
<tr>
<td>5</td>
<td>Foreman</td>
<td>Rp. 95,000.00</td>
<td>Rp. 19,768.79</td>
<td>Rp. 79,075.14</td>
<td>Rp. 193,843.93</td>
</tr>
<tr>
<td>6</td>
<td>Labour Supervision</td>
<td>Rp. 105,000.00</td>
<td>Rp. 21,849.71</td>
<td>Rp. 87,398.84</td>
<td>Rp. 214,248.55</td>
</tr>
</tbody>
</table>

For example in the temporary office facility & toilet work.

3.7.3.1. Total labor wages
(total cost per day x duration of work item x number of workers)
Workers = Rp. 142,832.37 x 5.00 x 6.00 = Rp. 4,284,971
Bricklayer = Rp. 163,236.99 x 5.00 x 3.00 = Rp. 2,448,555
Carpenter = Rp. 163,236.99 x 5.00 x 6.00 = Rp. 4,897,110
Foreman = Rp. 193,843.93 x 5.00 x 0.90 = Rp. 872,298.00
Foreman = Rp. 214,248.55 x 5.00 x 0.15 = Rp. 160,686 +
Total wages = Rp. 12,663,620

3.7.3.2. Cost slope
Cost slope = \( \frac{\text{crash cost} - \text{normal cost}}{\text{normal duration} - \text{crash duration}} \)
Cost slope / day = Rp. 1,987,434.87
Total Cost slope = Cost slope per day \( \times \) (normal duration - crash duration)
= Rp. 1,987,434.87 \( \times \) (7 - 5)
= Rp. 3,974,869.75

3.8. Analysis of Direct Costs and Indirect Costs
After the acceleration analysis process is complete, then calculate the total cost of the project in normal conditions and in conditions after being accelerated. These costs consist of direct and indirect costs. The following is the calculation of the total project cost.

Normal duration: 150 days
The duration after accelerating to 4 hours: 112 days
Budget plan: Rp. 8,759,200,000.00

In the previous calculation, the weight of the average direct cost of each work item was 91% and the weight of the indirect cost was 9% (6% profit and 3% overhead). Because profit and overhead are indirect costs, based on Presidential Decree 70/2012 on service provider profits is 0-15%, the profit is taken 6% of the total project cost and overhead 3% of the total cost. From the description above, you can find the value of profit and overhead costs in the following ways.

a. Profit = Total project cost \( \times \) 6% = Rp. 8,759,200,000.00 \( \times \) 6% = Rp. 525,552,000.00
b. Overhead costs = Total project cost \( \times \) 3% = Rp. 8,759,200,000.00 \( \times \) 3% = IDR. 262,776,000.00
c. Overhead per day = \( \frac{\text{overhead cost}}{\text{normal duration}} \) = \( \frac{\text{Rp. 262,776,000}}{150} \) = Rp. 1,751,840.00

After getting the value of profit and overhead costs, it can then calculate direct and indirect costs under normal conditions.
d. Direct cost = Total project cost \( \times \) 91% = Rp. 8,759,200,000 x 91% = Rp. 7,970,872,000
e. Indirect cost = profit + overhead costs = Rp. 525,552,000 + Rp. 262,776,000 = Rp. 788,328,000
f. Total project cost = Direct cost + Indirect cost = Rp. 7,970,872,000 + Rp. 788,328,000 = Rp. 8,759,200.00

After calculating the direct and indirect costs under normal conditions, then calculate the direct and indirect costs in the accelerated condition by adding 4 hours of overtime work.
g. Direct cost = Total normal direct costs + cost slope 4 hours of overtime
= Rp. 7,970,872,000.00 + Rp. 120,537,031.31 = Rp. 9,091,409,031.31
Indirect cost = (duration crashing \( \times \) overhead per day) + profit
= (112 \( \times \) Rp. 1,751,840.00) + Rp. 525,552,000.00
= Rp. 208,468,960.00 + Rp. 525,552,000.00 = Rp. 721,758,080.00
Total project cost = Direct cost + Indirect cost
= Rp. 8,091,409,031.31 + Rp. 721,758,080.00 = Rp. 8,813,167,111.31

4. Conclusion

Based on the results of the analysis and discussion of the analysis of time acceleration and cost of construction projects with the addition of four hours of work using the times cost trade off method in the construction project of the PT. X, it can be concluded that:

1. From the calculation results, it can be seen that the direct costs caused by the addition of four hours of overtime work, namely Rp. 8,091,409,031.31 and indirect costs of Rp. 721,758,080.00 so that the total cost of the project after being accelerated is Rp. 8,813,167,111.31 greater than the total planning cost of Rp. 8,759,200,000.00 or the difference of Rp. 53,967,111.31.

2. To avoid work delays that often occur on a project, it can be overcome by accelerating the project on work that is traversed by the critical path, where previously 10 days of delay can be exceeded even from the calculation results can be accelerated up to 38 days so that work can be accelerated from the duration the 150-day plan became 112 days much ahead of his planning.
References

Biographies
Anjas Handayani. Born in Jakarta on March 9, 1977. Worked as a lecturer at Mercu Buana University. He graduated with a Bachelor of Civil Engineering from Mercu Buana University in 1999 and obtained a master's degree in Civil Engineering with a concentration in Construction Management from Universitas Pelita Harapan Jakarta. Currently teaching several subjects such as Project Cost Estimation and Economic Engineering, Construction Management, Construction Quality Management Systems. Until now, he is also actively working in one of the BUMN subsidiaries in Indonesia.

Dodi Khoerul. Born in Tasikmalaya April 9, 1997. He pursued his undergraduate education in the Civil Engineering Study Program at Mercu Buana University and will graduate in 2021. Graduated from the State Vocational High School 2 Kota Tasikmalaya with a vocation in Building Drawing Engineering in 2015