Cost and Time Efficiency of Project Implementation with Time Cost Trade Off Method on Probolinggo-Banyuwangi Toll Road Projects STA 20 + 200 to STA 29 + 600

Mariyatul Chiftiyah, M. Ikhsan Setiawan, Sapto Budi Wasono
Faculty of Engineering, Civil Engineering Study Program
Narotama University Surabaya
mariyatul10@gmail.com, ikhsan.setiawan@narotama.ac.id, sapto.budiwasono@yahoo.com

Abstract

In project implementation there must be a variety of problems that can hamper so the project becomes longer than stipulated time. Crashing project is a method to shorten of project time by reducing time to less than normal time of activities that aim to optimize project time with lowest cost. One of crashing methods can be used is time cost trade off method. This method can be used to shorten time with lowest cost by adding work hours and increasing work shifts. The project as the object research is Probolinggo-Banyuwangi toll road project STA 20 + 200 to STA 29 + 600. The results showed that alternative 1 (the addition of 1 hour of overtime) was 1,51% more expensive than normal project costs and the duration was 0,07% faster than normal duration. For alternative 2 (addition of 2 hours overtime) 1.61% more expensive than normal project costs and 0,27% faster than normal duration. For alternative 3 (addition of 3 hours overtime) 1,46% more expensive than normal project costs and 0,58% faster than normal duration. Whereas for alternative 4 (the addition of work shifts) 0.78% is more expensive than the normal project costs and 3.15% faster than normal duration.

Keywords:
Crashing, Time Cost Trade Off, Toll Roads.

1. Introduction

According to Husen, (2010) Project is a combination of resources such as human, material, equipment and capital / costs collected in a temporary organization for achieve goals and objectives. In the course of project activities there must be a problem that can result in longer project times or project costs that swell from the planned budget.

Overcoming delays that occur in a project can be done by accelerating the project. Project acceleration can reduce duration of implementation but has an impact which can add to project costs. Therefore, accelerating steps must be able to reduce duration the project as much as possible with a small additional cost. One of the acceleration can be used is time cost trade off method.

This study aims to analyze cost and time efficiency of project implementation with time cost trade off method on the Probolinggo-Banyuwangi toll road project STA 20 + 200 to STA 29 + 600 with the alternative of adding 3 hours of overtime work and adding work shifts.

Limitation problems in this thesis research are as follows:
1. Only calculates cost and time efficiency that occurs after adding work hours and labor shifts.
2. The Microsoft Project 2013 program is only used to determine critical path
3. The unit price analysis used same as the Probolinggo-Banyuwangi toll road project STA 20 + 200 to STA 29 + 600
4. Does not take into account the availability of material when additional shifts occur.

2. Literature Review

According to Suanda, (2011) the project acceleration strategy is identical risk respons in risk management. It's just at risk that has occurred. The strategy is applied based on priority if there are a large number of factors causing project delays. The strategy that can be done is critical path must be communicated and agreed upon by the project team, conducting regular updates on the critical path (CPM), combining two or more jobs in critical path into one critical work, adding equipments to meet implementation needs, replacing less productive work with more productive work, increase work hours or overtime.

20
2.1. Project Management
According to Kerzner, (1982) in the book Ir. Iman Soeharto, (1999b) project management is planning, organizing, leading and controlling company resources to achieve short-term targets that have been determined. Furthermore, project management uses a vertical and horizontal system and hierarchy (activity flow) approach.

2.2. Direct Cost and Indirect Cost
Direct Cost are costs directly related to implementation of construction project work in the field. Direct costs on construction projects can be estimated by calculating work volume and project costs based on work unit price. Direct costs consist of material costs, labor costs, equipment costs (Martina, 2019).

\[
\text{Direct Costs} = \text{Normal Direct Costs} + \text{Cost Slope}
\]

Indirect cost are all project costs are not directly related to construction field. Even so, indirect costs must be available and can’t be released from ongoing projects. These indirect costs have not been explicitly calculated for each construction project but need to be estimated in order to allocate costs outside construction work. Costs that include indirect costs are unexpected costs, profits or overhead costs (Martina, 2019).

\[
\text{Indirect Cost} = \frac{\text{Indirect Cost Normal}}{\text{Normal Duration}} \times \text{New Duration}
\]

Thus, Total Cost = Direct Costs + Indirect Costs

2.3. Cost and Time Control
Organizing and leading the company’s resources to achieve targets will require efforts aimed at keeping jobwork can run without many deviations. This business is also called controlling which one of project management functions. Mockler, (1972) in the book Ir. Iman Soeharto, (1999a) argues that control is systematic effort to determine standards in accordance with planning goals, design information systems, compare implementation with standards, analyze likelihood of intersections between implementation and standards, then take corrective action is needed so that resources are used effectively and efficiently in order to achieve goals.

\[
\text{Figure 1. Relationship between normal and crash cost and time (Ir. Iman Soeharto, 1999a)}
\]

2.4. Time Cost Trade Off Method
According to Ervianto, (2004) understanding Time Cost Trade Off or TCTO is a deliberate, systematic, and analytic process in a way conduct testing off all activities in a project focused on critical path activities. Time cost trade off method intended to overcome problems such as project duration process that is not in accordance with contract duration, delays in the implementation of project activities, to get a bonus if project completin is accelerated or accelerate project schedule because avoids bad weather for the remaining project time.

3. Methodology
3.1. Research Sites
Projects that are the object of reserach is Probolinggo-Banyuwangi toll road project STA 20+200 to STA 29+600 with the following details:

<table>
<thead>
<tr>
<th>Role</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Owner</td>
<td>Jasa Marga Probolinggo-Banyuwangi</td>
</tr>
<tr>
<td>Contractor</td>
<td>PT. PP-GNG, KSO</td>
</tr>
<tr>
<td>Planning Consultant</td>
<td>PT.Buana Archicon, PT.Mega Trustlink, PT.Maratama Cipta Mandiri</td>
</tr>
<tr>
<td>Implementation Time</td>
<td>730 days</td>
</tr>
<tr>
<td>Start Work</td>
<td>November 1, 2019</td>
</tr>
</tbody>
</table>
3.2. Data Collection

In this study took data on Thursday April 9, 2020 from the project used as research object is primary data and secondary data from Probolinggo-Banyuwangi toll road project STA 20+200 to STA 29+600. Primary data obtained is time schedule that includes activities type, activities percentage and activities duration, RAB (Budget Plan) and work unit price. And secondary data obtained is a list worker’s salary and equipment prices.

3.3. Research Procedure

Procedure in this study are carried out as follows:

1. Finding a literature study on project acceleration with time cost trade off method
2. Collection of primary and secondary data from the research object project
3. Determine the critical path with Microsoft Project
4. Analysis crash duration and crash cost. Implementation of acceleration can be done with alternative following:
   a. Addition of 3 working hours

In addition to the work hours of the project there will be decrease in labor productivity an hour. The coefficient of productivity reduction can be seen in table 1 as follows.

<table>
<thead>
<tr>
<th>Overtime Hours</th>
<th>Decrease in Productivity Index</th>
<th>Work Performance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>0,1</td>
<td>90</td>
</tr>
<tr>
<td>2 hours</td>
<td>0,2</td>
<td>80</td>
</tr>
<tr>
<td>3 hours</td>
<td>0,3</td>
<td>70</td>
</tr>
</tbody>
</table>

Source : (Soeharto, 1999)

Steps in calculating crash duration are:

1) Calculate daily productivity
   \[
   \text{Daily Productivity} = \frac{\text{Volume}}{\text{Normal Duration}}
   \]

2) Calculate productivity every hour
   \[
   \text{Productivity every hour} = \frac{\text{Daily Productivity}}{8 \text{ hours}}
   \]

3) Calculate daily productivity after crash
   \[
   \text{Daily productivity after crash} = \text{Daily productivity} + (a \times b \times \text{productivity every hour})
   \]

4) Calculate crash duration
   \[
   \text{Crash Duration} = \frac{\text{Volume}}{\text{Daily productivity after crash}}
   \]

Steps in calculating crash cost are:

1) Calculate normal daily work salary
   \[
   \text{Daily work salary} = \text{daily productivity} \times \text{unit price of salary}
   \]

2) Calculate normal hourly
   \[
   \text{Hourly work salary} = \text{productivity every hour} \times \text{unit price of salary}
   \]

3) Calculate overtime salary daily (1 hour, 2 hours, 3 hours)
   a) Overtime work 1 hour = 1,5 x normal hourly salary
   b) Overtime work 2 hours = (1,5 x normal hourly salary) + (2 x normal hourly salary)
   c) Overtime work 3 hours = (1,5 x normal hourly salary) + 2 (2 x normal hourly salary)

4) Calculate crash cost of labor everyday
   \[
   \text{Crash cost every day} = \text{daily salary} + \text{overtime salary (1 hour/ 2 hours/ 3 hours)}
   \]

5) Calculate crash cost of labor = crash cost every day x crash duration

6) Calculate additional hours used equipment
   \[
   \text{Daily cost equipment} = \text{daily productivity equipment} \times \text{equipment price}
   \]

7) Calculate cost equipment every hour
   \[
   \text{Cost equipment every hour} = \text{productivity every hour} \times \text{equipment price}
   \]

8) Calculate crash cost equipment = daily cost equipment + cost equipment 1 hour/ 2 hours/ 3 hours

9) Calculate crash cost total = crash cost labor + crash cost equipment

10) Calculate cost slope
    \[
    \text{Cost slope} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal duration} - \text{Crash duration}}
    \]
a) Increase Workforce Shift
1) Steps in calculating crash duration:
2) Calculate daily productivity
\[
\text{Daily productivity} = \frac{\text{Volume}}{\text{Normal Duration}}
\]  
3) Calculate productivity after crash
\[
\text{Productivity after crash} = \text{daily productivity} + (\text{daily productivity} \times 11\%)
\]  
4) Calculate crash duration
\[
\text{Crash duration} = \frac{\text{Volume}}{\text{Daily productivity after crash}}
\]

Steps in calculating crash cost:
1) Night shift salary = (15\% \times \text{daily salary}) + \text{daily salary}
2) Total salary after crash = (\text{daily salary} + \text{night shift salary}) \times \text{crash duration}
3) Crash cost total = \text{normal cost} + \text{total salary after crash}
4) Calculate cost slope
\[
\text{Cost slope} = \frac{\text{Crash cost total} - \text{Normal cost}}{\text{Normal duration} - \text{Crash duration}}
\]

1. Results and discussion with these alternatives. The results obtained are the optimum time and minimum cost.
2. Provide conclusions and development suggestions.

4. Result and Discussion

Acceleration of the project with time cost trade off method in this study will be carried out on the critical path. Determine this critical path using Microsoft Project. The following is a list of critical activity path in this project:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Work</th>
<th>Duration of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cutting of trees d&gt;30 cm-50 cm</td>
<td>76 days</td>
</tr>
<tr>
<td>2</td>
<td>Cutting of trees d&gt;50 cm-75 cm</td>
<td>48 days</td>
</tr>
<tr>
<td>3</td>
<td>Cutting of trees d&gt;75 cm</td>
<td>29 days</td>
</tr>
<tr>
<td>4</td>
<td>Cleaning of workplaces</td>
<td>144 days</td>
</tr>
<tr>
<td>5</td>
<td>Excavation of soft stones for disposal</td>
<td>486 days</td>
</tr>
<tr>
<td>6</td>
<td>Grained material heap</td>
<td>420 days</td>
</tr>
<tr>
<td>7</td>
<td>Excavation structure depth 0-2 m</td>
<td>125 days</td>
</tr>
<tr>
<td>8</td>
<td>Excavation structure depth 2-4 m</td>
<td>87 days</td>
</tr>
<tr>
<td>9</td>
<td>Excavation structure depth &gt;4 m</td>
<td>73 days</td>
</tr>
<tr>
<td>10</td>
<td>Pairs of blinding stone</td>
<td>390 days</td>
</tr>
<tr>
<td>11</td>
<td>Preparation of subgrade</td>
<td>195 days</td>
</tr>
<tr>
<td>12</td>
<td>Layers of drainage</td>
<td>70 days</td>
</tr>
<tr>
<td>13</td>
<td>Lean concrete (t=10 cm)</td>
<td>42 days</td>
</tr>
<tr>
<td>14</td>
<td>Pavement concrete</td>
<td>120 days</td>
</tr>
<tr>
<td>15</td>
<td>Road markings Type A-1 (General application)</td>
<td>120 days</td>
</tr>
</tbody>
</table>

4.1. Addition of Working Hours

Acceleration of the duration that will be done in the presence of the addition of work hours or overtime in this study will be calculated every hour. The addition of maximum overtime hours provided in this study is 3 hours. In Law of the Republic of Indonesia No.13 of 2003 concerning Manpower, (2003) article 77 paragraph 1 states that the limitation of working hours in a week is 40 working hours both in the 5 working days system and the 6 working days system a week. Working hours that exceed 3 hours of working hours every day or 14 hours every week are not permitted either in accordance with Law of the Republic of Indonesia No.13 of 2003 concerning Manpower, (2003) Manpower article 78 or in terms of the health of workers.

Calculation the acceleration of the duration by adding 1 hour, 2 hours and 3 hours of work can use the formula above, the result are as follows.
4.2. Addition of Labor Shifts

Addition shift for night shift has an impact is affecting productivity of workers, the potential for errors and increase accidents, less lighting and others. To reduce impact caused by working, one day can be done in two shifts, morning shift (08.00 AM-05.00 PM) and night shift (06.00 PM-03.00 AM).

Calculation the acceleration of duration and cost slope with addition of labor shifts can use the formula above, the result are as follows.
Table 5. Table Calculation of Crash Duration and Cost Slope Addition of Workforce Shift

<table>
<thead>
<tr>
<th>No</th>
<th>Name of Work</th>
<th>Normal Duration</th>
<th>Crash Duration</th>
<th>Cost Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cutting of trees d&gt;30 cm-50 cm</td>
<td>76</td>
<td>40</td>
<td>Rp 6,621,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Cutting of trees d&gt;50 cm-75 cm</td>
<td>48</td>
<td>25</td>
<td>Rp 8,014,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Cutting of trees d&gt;75 cm</td>
<td>29</td>
<td>15</td>
<td>Rp 33,047,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Cleaning of workplaces</td>
<td>144</td>
<td>76</td>
<td>Rp 78,528,000.00</td>
</tr>
<tr>
<td>5</td>
<td>Excavation of soft stones for disposal</td>
<td>486</td>
<td>257</td>
<td>Rp 654,309,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Grained material heap</td>
<td>420</td>
<td>222</td>
<td>Rp 20,962,000.00</td>
</tr>
<tr>
<td>7</td>
<td>Excavation structure depth 0-2 m</td>
<td>125</td>
<td>66</td>
<td>Rp 50,168,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Excavation structure depth 2-4 m</td>
<td>87</td>
<td>46</td>
<td>Rp 43,753,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Excavation structure depth &gt;4 m</td>
<td>73</td>
<td>39</td>
<td>Rp 65,049,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Pairs of blinding stone</td>
<td>390</td>
<td>206</td>
<td>Rp 7,625,000.00</td>
</tr>
<tr>
<td>11</td>
<td>Preparation of subgrade</td>
<td>195</td>
<td>103</td>
<td>Rp 18,913,000.00</td>
</tr>
<tr>
<td>12</td>
<td>Layers of drainage</td>
<td>70</td>
<td>37</td>
<td>Rp 240,311,000.00</td>
</tr>
<tr>
<td>13</td>
<td>Lean concrete (t=10 cm)</td>
<td>42</td>
<td>22</td>
<td>Rp 28,902,000.00</td>
</tr>
<tr>
<td>14</td>
<td>Pavement concrete</td>
<td>120</td>
<td>63</td>
<td>Rp 668,188,000.00</td>
</tr>
<tr>
<td>15</td>
<td>Road markings Type A-1 (General application)</td>
<td>120</td>
<td>63</td>
<td>Rp 8,903,000.00</td>
</tr>
</tbody>
</table>

4.3. Direct and Indirect Cost

Project total cost consist of direct and indirect cost. With the acceleration of the duration it will affect the project total cost.

Table 6. Recapitulation Direct and Indirect Cost

<table>
<thead>
<tr>
<th>Methods</th>
<th>Duration</th>
<th>Direct Cost</th>
<th>Indirect Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Condition</td>
<td>730 days</td>
<td>Rp 1.087.814.000.00</td>
<td>Rp 107.586.000.00</td>
<td>Rp 1.195.400.000.00</td>
</tr>
<tr>
<td>Addition 1 hour Overtime</td>
<td>729 days</td>
<td>Rp 1.106.205.030.00</td>
<td>Rp 107.509.582.00</td>
<td>Rp 1.213.714.612.00</td>
</tr>
<tr>
<td>Addition 2 hours Overtime</td>
<td>728 days</td>
<td>Rp 1.107.618.612.00</td>
<td>Rp 107.291.244.00</td>
<td>Rp 1.214.909.856.00</td>
</tr>
<tr>
<td>Addition 3 hours Overtime</td>
<td>726 days</td>
<td>Rp 1.106.205.041.00</td>
<td>Rp 106.960.058.00</td>
<td>Rp 1.213.165.099.00</td>
</tr>
<tr>
<td>Addition Workforce Shift</td>
<td>707 days</td>
<td>Rp 1.100.516.623.00</td>
<td>Rp 104.254.788.00</td>
<td>Rp 1.204.771.411.00</td>
</tr>
</tbody>
</table>

4.4. Efficiency Cost and Time Project

1. Efficiency addition of 1 hour overtime

\[
\text{Cost efficiency} = \frac{\text{Crash project cost}}{\text{Normal project cost}} \times 100\% = \frac{\text{Rp 1,213,714,612,000.00}}{\text{Rp 1,195,400,000,000.00}} \times 100\% = 1.51\%
\]
Time efficiency = \( \frac{\text{Normal duration} - \text{Crash duration}}{\text{Crash duration}} \times 100\% \)

\( \frac{730}{729} \times 100\% = 0.07\% \) 

2. Efficiency addition of 2 hours overtime

\[
\text{Cost efficiency} = \frac{\text{Crash project cost}}{\text{Normal project cost}} \times 100\%
\]

\[
= \frac{\text{Rp} 1,214,909,856,000,00}{\text{Rp} 1,195,400,000,000,00} \times 100\% = 1.61\%
\]

\[
\text{Time efficiency} = \frac{\text{Normal duration}}{\text{Crash duration}} \times 100\% = \frac{730}{728} \times 100\% = 0.27\%
\]

3. Efficiency addition of 3 hours overtime

\[
\text{Cost efficiency} = \frac{\text{Crash project cost}}{\text{Normal project cost}} \times 100\%
\]

\[
= \frac{\text{Rp} 1,213,165,099,000,00}{\text{Rp} 1,195,400,000,000,00} \times 100\% = 1.46\%
\]

\[
\text{Time efficiency} = \frac{\text{Normal duration}}{\text{Crash duration}} \times 100\% = \frac{730}{728} \times 100\% = 0.58\%
\]

4. Efficiency addition of workforce shifts

\[
\text{Cost efficiency} = \frac{\text{Crash project cost}}{\text{Normal project cost}} \times 100\%
\]

\[
= \frac{\text{Rp} 1,204,771,411,000,00}{\text{Rp} 1,195,400,000,000,00} \times 100\% = 0.78\%
\]

\[
\text{Time efficiency} = \frac{\text{Normal duration}}{\text{Crash duration}} \times 100\% = \frac{730}{728} \times 100\% = 3.15\%
\]

Efficiency after the acceleration shows that costs are more increases than normal cost and time is faster than normal project time. Project acceleration can be assessed for efficiency if it has fewer project cost increments with more time acceleration.

5. Conclusions and Suggestions

Based on the results of the analysis and discussion in this final project, the results of the research crashing on the Probolinggo-Banyuwangi toll road project STA 20 + 200 to STA 29 + 600 can be concluded as follows.

1. Total cost of the normal project is Rp 1,195,400,000,000,00 with project duration of 730 days. From the results of the analysis of this study the condition after crashing with alternative 1 (the addition of 1 hour of overtime work) obtained Rp 1,213,714,612,000,00 or more expensive Rp 18,314,612,000 (1.51%) of normal project costs and duration to 729 days or 0.07% faster than the normal duration, for alternative 2 (addition of 2 hours overtime) obtained Rp 1,214,909,856,000,00 or more expensive Rp 19,509,856,000,00 (1.61%) of normal project costs and duration becomes 728 days or 0.27% faster than normal duration, for alternative 3 (addition of 3 hours overtime) obtained Rp 1,213,165,099,000,00 or more expensive Rp 17,765,099,000,00 (1.46%) from of normal project costs and duration to 726 days or 0.58% faster than the normal duration, while for alternative 4 (additional work shifts) obtained Rp 1,204,771,411,000,00 or more expensive Rp 9,371,411,000,00 (0.78%) of normal project costs and duration to 707 days or 3.15% faster than normal duration.

2. With Implementing the crashing method with the addition of work shifts (morning shift and night shift) is a more effective and economical crashing method, because with the alternative of adding work shifts the duration of work is faster than the duration of the project with the addition of 1 hour, 2 hours and 3 hours overtime and total Project costs are lower than the total project costs after acceleration with the alternative of adding 1 hour, 2 hours and 3 hours overtime.

Suggestions used for further research are as follows.

1. For the alternative acceleration used should be adjusted to the project conditions and the availability of existing human and material resources.

2. The process of acceleration (crashing) should be done with other alternatives in order to produce a more effective and efficient comparison.

6. Acknowledgement

Praise to be Allah for given blessing and mercy to the writer to complete the journal. The writer really gives her regards and thanks for Mr. Dr. M. Ikhsan Setiawan, S.T., M.T and Mr. Sapto Budi Wasono, S.T, M.T.
for their best guidance and help. To all my friends and relatives for give support, either morally, financially and physically.

References