

An Analysis of Time and Cost Optimization by Employing Time Cost Trade off (Tcto) Method In The Construction Project Of Integrated Student Dormitory of Madrasah TSANAWIYAH NEGERI (MTsN) 1 MALANG

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ABSTRACT

An optimization evaluation is conducted to seek the profit and loss within a construction project. Madrasah Tsanawiyah Negeri (MTsN) 1 Malang has been built an Integrated Student Dormitory building in 2020. The project construction was carried out by PT. Bangun Sarana Mandiri Utama where the project implementation took time for 119 calendar days by 24-hour of working hours with the value of structural work contract stated as IDR.3,262,141,336,- in 119 calendar days implementation time. In a large quantity of work that must be completed, the accuracy or precision in conducting the project optimally was very necessary, in particular on the structural works, since in principle it covers the entire building. When each item of works can be accelerated then it can bring a benefit in the aspect of time. Evaluation in a form of an analysis to determine the optimization level of the project is referred to the government regulations regarding the provision of overtime working hour. As one of the efforts to optimize the cost and time of the project, the application of Time Cost Trade Off (TCTO) method, by addition of overtime working hours with a maximum of 3 hours, then, the optimal time for overtime hours is 1 hour for 7 days, with the acceleration duration of 118 days for structural work completion compared to the normal duration of completion of 119 days with the total cost required is IDR.3,591,360,000,00 or there is an additional cost of IDR.139,543,000.00 within the project.

Keywords: evaluation of implementation, construction project, time acceleration, Time Cost Trade Off

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I. INTRODUCTION

For a project, whether during the construction period or after the building has been completed, certainly there must be several evaluations regarding the aspect of time and cost to assess the profit also the lost of the related construction work, meanwhile some constraints which usually experienced related to time and costs are delay of work implementation, where the target of time completion is already determined but there are many adjustments must be tailored to field conditions along with other factors that influence it, both in terms of manpower and the work location, therefore, when there is an addition in time of what has been designed, it will also have an impact on the costs that must be incurred to be able to meet the extra time.

The Integrated Student Dormitory Building of MTsN 1 Malang became one of the follow-up project held in 2020. Yet, it needs a further evaluation since in reality the agreed time did not match with the time implementation on the workfield, where there was overtime activities up to 24 hours existed and made the work activities that carried out continuously became very ineffective. Not only disrupting teaching and learning activities indirectly, but also not enough time to carry out a job evaluation and held regular meetings to find out the constraints and seek solutions of these obstacles. If the work is in accordance with the estimated/determined time, then it is certain that the construction work for this dormitory building experiencing a delay.

From the background description above, then, the formulation of the study problems constructed into:

1. What is the acceleration duration or how much project time can be reduced by employing the *Time Cost Trade Off* (TCTO) to the Integrated Student Dormitory Project of MTsN 1 Malang?
2. What are the implementation stages for calculating the optimum time and cost due to additional working hours in the Integrated Student Dormitory Project of MTsN 1 Malang?

3. How much is the additional cost of the project after the existence of additional working hours?

II. LITERATURE REVIEW

2.1. Optimization Analysis

In this study, an optimization analysis defines as a process of describing the project duration to get the best (optimal) duration acceleration by applying many alternatives in terms of cost. The process of shortening the activity time in the network to reduce time on the critical path, so the total time completion can be reduced is called as a crashing project(Heizer and Render, 2005).

2.2. A Relationship of Cost with Time

The cost-to-time relationship of the total project cost is the sum of the direct costs and indirect costs used during project implementation. The amount of this cost is very dependent on the length of time (duration) for project completion, where both costs can change accordingly to time and progress of the project. Although it cannot be calculated with a certain formula, the general rule is the longer the project runs the higher the cumulative indirect costs requirement (Soeharto, 1999).

2.3. Additional Workforce

For adding the number of heavy equipments and workforce to the work, the consideration is about whether the available work space is too narrow or quiet wide, because adding workforce to a work activity should not interfere with another workforce that conducting other work activities which run at the same time. Moreover, it requires an equal supervision because a crowded work space that lack of supervision will reduce the worker's productivity (Ichwan and Impol, 2021).

2.4. Additional Costs

An addition of working time will increase the labor cost from the normal labor cost. According to the Government Regulation of the Republic of Indonesia Number 35 of 2021,Article 31, "Companies that employ workers or laborers beyond their working hours as referred to in Article 21 paragraph (2) are required to pay overtime wages provided that the additional working time for the first hour, the workers will get arise of 1,5 times the normal hourly wage and for the next additional working hours, the worker will get 2 times the normal hourly wage".

2.5. Additional Working Hours (Overtime)

According to Government Regulation of the Republic of Indonesia Number 35 of 2021 article 21 paragraph 2, working hours are:

- a. 7 (seven) hours 1 (one) day and 40 (forty) hours 1 (one) week for 6 (six) working days in 1 (one) week; or
- b. 8 (eight) hours 1 (one) day and 40 (forty) hours 1 (one) week for 5 (five) working days in 1 (one) week.

While overtime is working time that exceeds the week for 6 (six) working days in 1 (one) day, 7 (seven) hours a day and 40 (forty) hours 1 (one) week or 8 (eight) hours a day and 40 (forty) hours 1 (one) week for 5 (five) working days in 1 (one) week or working hours on weekend(rest days) and/or on official holidays determined by the government.

Addition of working hours (overtime) is one strategy commonly selected to speed up the process of completing a project. The normal time for workers to work every day is 7 hours (starting at 08:00 and finishing at 16:00 with one hour break, namely at 12:00 -13:00). Then when normal working hours are over, overtime work can start (Sulistyo and Al-Fikri, 2021).

Adding the working hours as overtime can be done by adding 1 hours and 2 hours according to the desired time and paying attention to the workers' condition. An important consideration when determining an overtime hour is the greater the overtime hour addition, then, the lower the worker's productivity will be.

2.6. Project Scheduling

For completing a construction work, scheduling is one crucial component which needs to be considered. In scheduling, not only allocation of the available time must be considered but also determining other limitations so that the project completion can be carried out in optimum way. By project schedule, it can be traced whether the project has been working according the schedule plan and able to view the progress of the project. From the schedule, it can be seen whether the project has work well or not, and whether the project has been carried out according as planned (Fikri and Luthan, 2021).

Scheduling is made by following developments in project implementation, because one project is different from another. This is done in order to obtain a realistic schedule in accordance with the existing project conditions so that the allocation of resources and the time duration are in accordance with the goals and objectives of the project. In the scheduling process, the arrangement of activities and the relationship between activities must be made in detail so that they can assist in project evaluation (Saputra, et.al. 2021).

Critical Schedule is the elaboration of project planning into a sequence of work implementation steps to achieve the target. The time factor has been included in the schedule. A well-known method of developing schedules is network analysis, which depicts in a graphic way the relationship between the sequences of project work.

Work that must precede or be preceded by other work is identified in terms of time. This network is very useful for project planning and control (Angelin and Ariyanti, 2019).

2.7. Method of Time Cost Trade Off (TCTO)

Accelerating the project completion time is an attempt to complete the project earlier than the completion time under normal circumstances. There are several ways that can be used to accelerate the project time (Pratiwi et.al., 2022) These methods are include:

- a. Increase in the number of working hours
- b. Additional workforce
- c. Definition or discussion of equipment
- d. Selection of quality human resources
- e. Use of effective construction methods

This method can be carried out separately or in combination, for example a combination of adding working hours as well as adding labor/workforce, commonly called shifts, where the work unit for morning to afternoon is different from the work unit for afternoon to evening.

The normal working hours for workers is 7 hours (starting at 08.00 and ending at 16.00 with one hour break), then overtime is carried out after the normal working hours are over. Additional working hours (overtime) can be done by discussing 1 hour to 4 hours in accordance with the additional overtime hours, which can cause productivity decrease, an indication of a decrease in worker productivity due to working hours (overtime).

- a. Daily productivity
- b. Productivity every day
- c. Daily productivity after crash

Whereas the wages for additional work are vary. In the first hour overtime, the workers get an additional hourly wage of 1.5 times the normal hourly wage, and in the next additional working hours, the worker will get 2 times the normal hourly wage. From this description, the wages can be formulated as follows:

The Overtime cost each day = $(Jk1^1 \times 1,5 \times \text{wage per one hour normal time} + (Jk1^2 \times 2 \text{ Wage of one hour normal time})$

Where:

$Jk1^1$ = *Jam kerjalemburpertama* (the first hour of overtime)

$Jk1^2$ = *Jam kerjalemburberikutnya* (the next hour of overtime)

2.8. Microsoft Project Program Software

In Wowor's research (2013) reported that *Microsoft Project* is a part of Microsoft Office Professional which is able to process data related to construction project activities. Several benefits from Microsoft Project are described as follows.

1. Store details of a project in its database which includes tasks and their relationship to each other, type of resources used, costs, critical path and others.
2. Use these information to calculate and maintain the project schedule, costs, and other elements including creating a project plan.
3. Tracking during the project to determine whether the project will be completed on time and within the planned budget or not.

As for types of project management methods which is popular today include CPM (Critical Path Method), PERT (Program Evaluation Review Technique), and Gantt Chart. The Microsoft Project is an amalgamation of the three methods. It is also a planning system that can assist in the schedule preparation (scheduling) for a project or series of work. Microsoft Project also helps to record and monitor resource users, both in the form of human resources and in the form of equipment.

The purpose of scheduling in Microsoft Project include:

1. Know the project work duration.
2. Make the optimum duration.
3. Take control in the finished schedule
4. Allocating the resources used.

Whereas the components that required on the schedule are:

1. Activities (details of tasks, main tasks).
2. Duration of work for each work
3. The working relationship of each activity.
4. Resources (labor and materials).

In the Microsoft Project program, there are several tasks to do such as:

1. Records the need for labor in each activity.
2. Records the working hours of employees and overtime hours.
3. Calculates expenses in relation to labor costs, entering fixed costs, calculating the total cost of the project.
4. Helps control over allocation (excess burden on labor usage).

The following discussion is showing the Microsoft Project appearance related to this study.

1. Initial display when opening the Microsoft Project (Gantt Chart View). The initial display will show a table on the left side of the screen and the scheduling column on the right side of the screen.

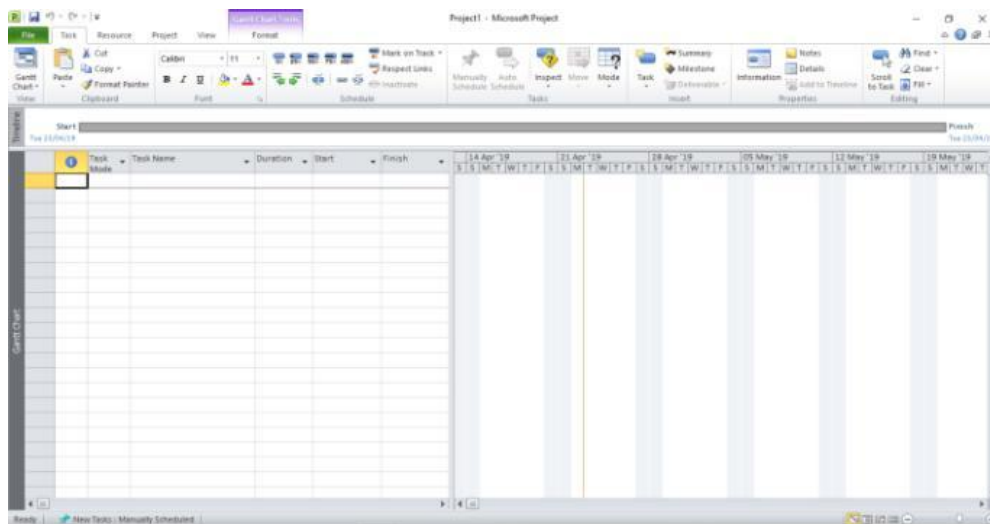


Figure 2.1. The Initial Display of Microsoft Project (Gantt chart view)

2. Taskis a form of worksheet in Microsoft Project that contains details of the project work.

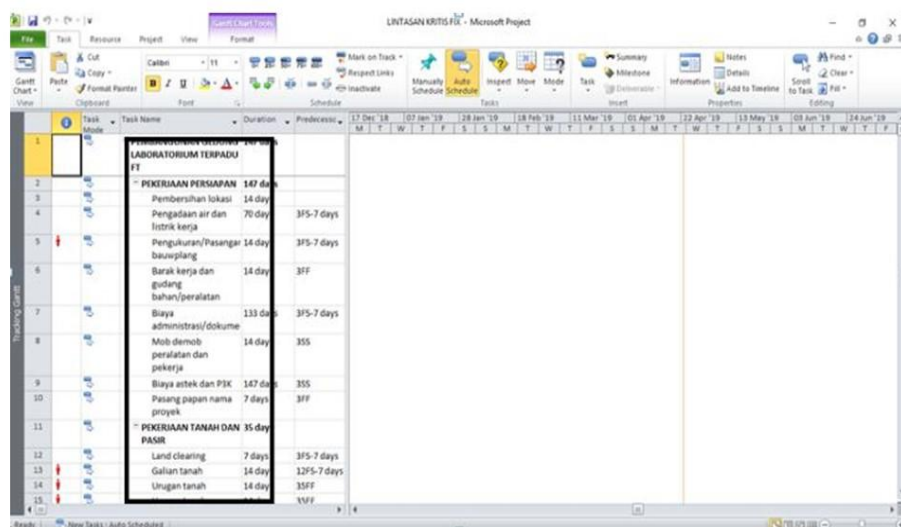


Figure 2.2. The Task Page

3. *Duration*, as the period of time required to complete a project.

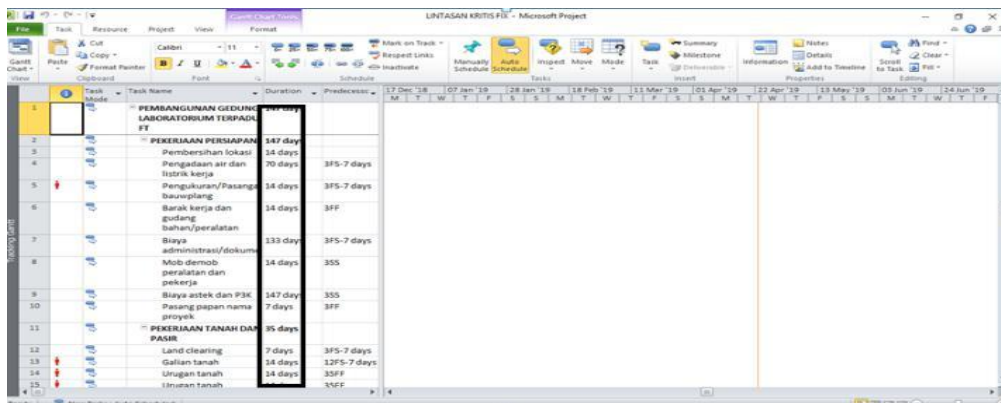


Figure 2.3. The *Duration* Column

4. *Begin/Start*, In this column there is the start date of an activity that has been planned.

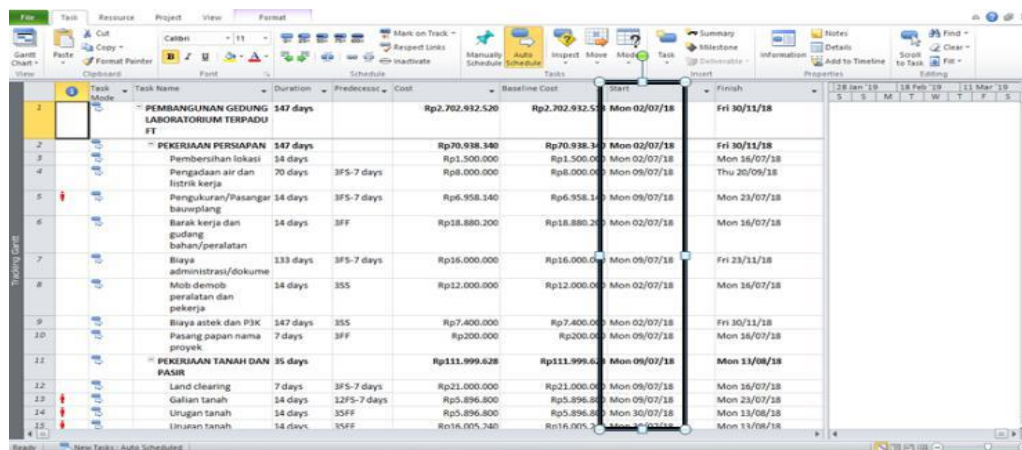


Figure 2.4. The *start* Column

5. *Complete/Finish*. This column contains the end date of a project which automatically filled (calculated) dated back from the start date of the project.

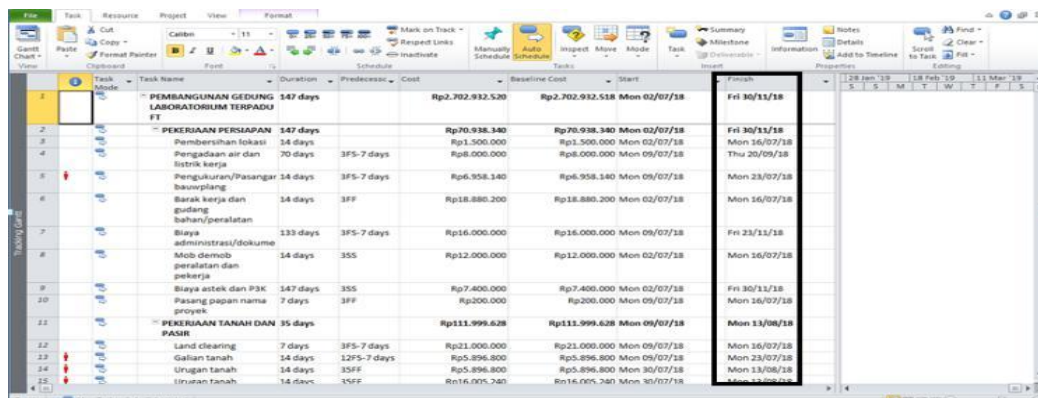
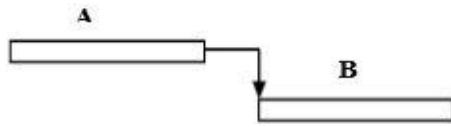


Figure 2.5. The *Finish* Column

6. *Predecessor*, is the link between one activities to another activities. There are four types of interrelationship between works, which are:

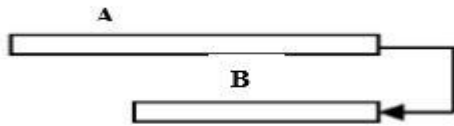
- a. FS (*Finish to Start*)

A new work may be started (B) if another work (A) is finished.



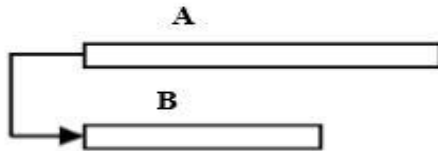
b. FF (Finish to Finish)

A work (A) must be completed simultaneously with the completion of another work (B).



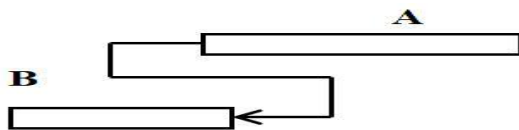
c. SS (Start to Start)

A work (A) must begin/start at the same time as another work (B)



d. SF (Start to Finish)

A new work (B) may end if another work (A) starts



e. Bar Chart

The bar chart display in Microsoft Project appear in horizontal bar formats that describe the work duration.

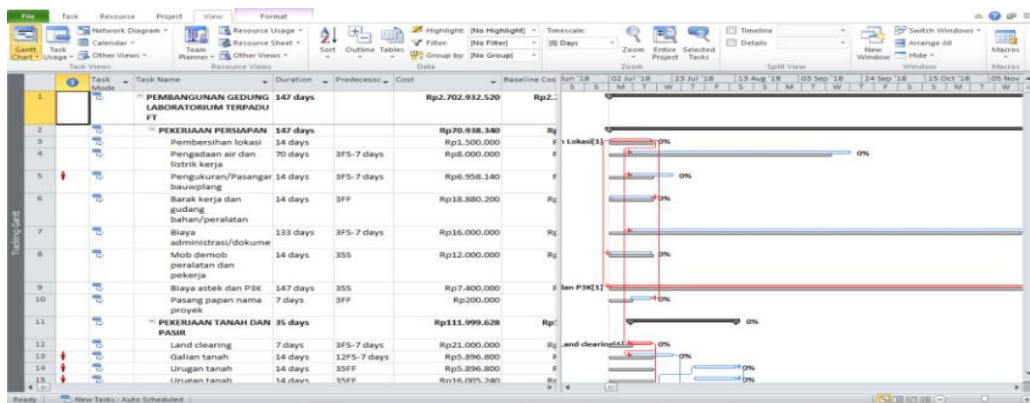


Figure 2.6. The Bar Chart Display

III. RESEARCH METHOD

3.1. The Research Implementation Stages

This study is focused on acceleration analysis of the building construction time by applying *Time Cost Trade Off* (TCTO) method with study location on the Integrated Student Dormitory Building Project of MTsN 1 Malang. Based on the purpose and problem formulation, the most appropriate research is a descriptive and quantitative research.

3.2. Data Collection

Data collection or information from a construction project implementation which is very useful for conducting an evaluation to time and cost optimization are taken from the required data which was the secondary data or the data obtained from agencies such as contractors, supervisory consultants, and others. Whereas variables that greatly affect the time and cost optimization of this project are the time variable and the cost variable.

Type of data influences the time variable were obtained from PT. Bangun Sarana Mandiri Utama as the project contractor, where the type of data needed for the time variable of this study are:

1. Cumulative progress data (S-curve), including:
 - a. Type of activity
 - b. Activity Percentage
 - c. Activity Duration

2. Recapitulation of project cost calculations

As for data required for the cost variable in this study are:

1. List of the bidding Cost Management Plan (*Rencana Anggaran Biaya*) including:
 - a. The amount of normal cost
 - b. The normal duration
 - c. The Unit Price Analysis
2. The Price List of Materials and Wages
3. Unit Price Analysis

3.3 Data Analysis

The necessary data for this study are the S-curve, cost management plan (RAB), and unit price analysis. In this stage, the TCTO (Time Cost Trade Off) analysis will be reviewed to determine the optimum cost and time as well as the calculation of the cost and time efficiency as a comparison of before and after project acceleration. The research methods applied in this study are data collection method and analysis method.

Data analysis was carried out by inputting the critical path data. Once the critical path obtained, each worker activity situated on the critical data then being analyzed with the TCTO method (addition of overtime and workforce to facilitate the analysis and the calculation). Result from this analysis is the acceleration of project duration and increase in costs due to acceleration duration in each accelerated work activity. A rise in cost was due to the addition of overtime hours and addition of workers/workforce (Pratiwi, et al., 2022).

In the process of analysis each variable will be operationally defined. The operational definition is the translation of one research variable into detailed indicators. The operational definition from the research variables are explained below:

1. The optimal time for a project.

Time, related to this discussion, is the length of a series when the process takes place, as an elaboration of project planning into a sequence of activity steps to achieve the goal. The optimal project time is the best completion time of a project or a relative short time of a project completion.

2. The duration of a project

Project duration is the amount of time required to complete all project work.

3. Dependency relationship between project activities

The dependency relationship between project activities is related to which activity must take precedence or be carried out and it can also be seen that an activity cannot be started if the previous activity has not been completed.

4. The Budget Plan/ Cost Management Plan (RAB) of a project

Project costs are the budget spent on project implementation in the form of financial fund to carry out project within a certain period of time.

The research stages that will be conducted in this research are presented in research flowchart as appear in the following figure.

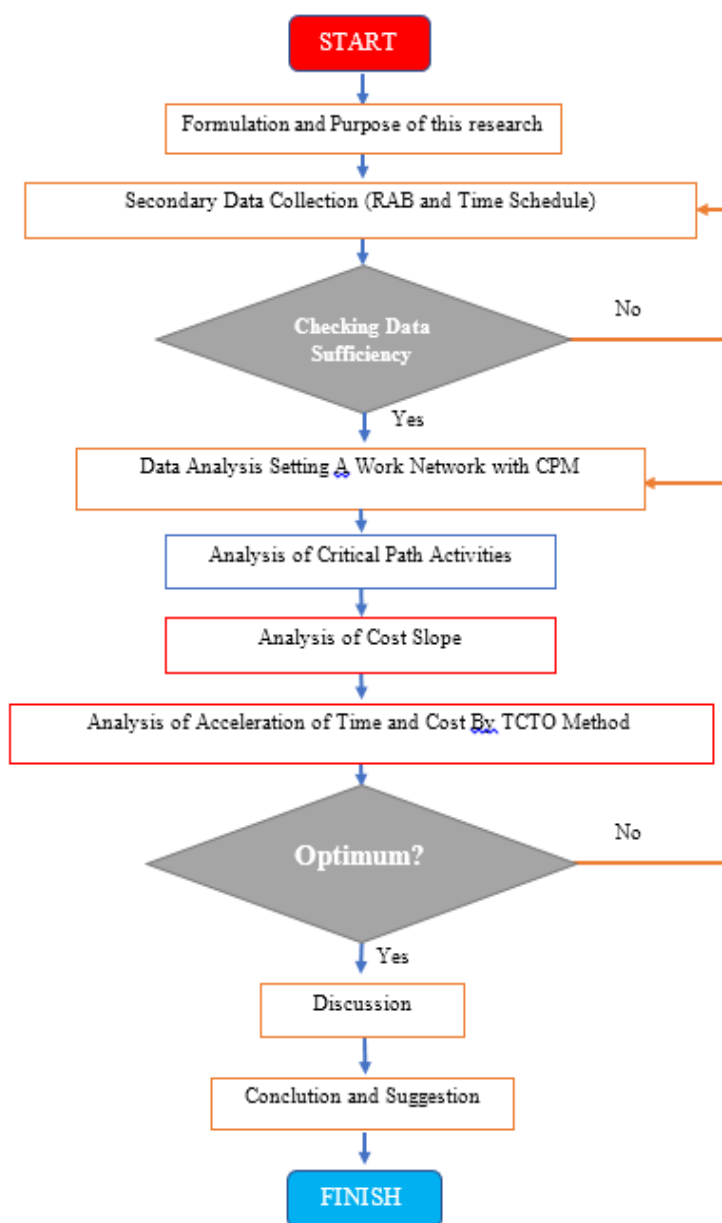


Figure 3.4. The Research Flowchart

IV. RESULT AND DISCUSSION

4.1 Identification of Project Financing

In the Integrated Student Dormitory building project, the contract value is IDR.7,044,428,000, - with a total value for structural work is IDR. 3,262,141,000, -. As the initial step for project optimization in structural work using TCTO, data will be collected in the form of direct costs and indirect costs.

4.1.1 Indirect Cost of A Project

Indirect Costs are costs that are not directly related to construction, but must exist to support the course of work in a construction project, these indirect costs can be in the form of overhead costs, profits, unexpected costs and value added tax (PPN).

a. OverheadCost

Overhead costs are the cost for paying project staff salary and also field facility cost in the MTsN 1 Malang Integrated Student Dormitory building project with total cost of IDR. 750,000.00,-

As for the staff involved in working overtime at the project site are field implementer and supervisors. Details of overtime costs that must be incurred for staff in the project site are:

$$\begin{aligned} \text{Total salary for staff in a day} &= \text{Field Implementer} + \text{Supervisor Salary} \\ &= \text{IDR. 400.000,00} \\ \text{Total salary for staff in an hour} &= \frac{\text{Total salary in a day}}{\text{Normal working hour}} \\ &= \frac{\text{IDR. 400.000,00}}{7 \text{ hours}} \\ &= \text{IDR. 57.142,85} \end{aligned}$$

Thus, total salary for staffs in a day from 1 hour to 3 hours are calculated as:

- Total overtime salary for staff for 1 hour
 $= (\text{Jkl}^1 \times 1,5 \times \text{total salary per hour})$
 $= (1 \text{ jam} \times 1,5 \times \text{IDR. 57.142,85})$
 $= \text{IDR. 85.714,27}$
- Total overtime salary for staff for 2 hours
 $= (\text{Jkl}^1 \times 1,5 \times \text{total salary per hour}) + (\text{Jkl}^1 \times 2 \times \text{total salary per hour})$
 $= (1 \text{ hour} \times 1,5 \times \text{IDR. 57.142,85}) + (1 \text{ hour} \times 2 \times \text{IDR. 57.142,85})$
 $= \text{IDR. 199.999,97}$
- Total overtime salary for staff for 3 hours
 $= (\text{Jkl}^1 \times 1,5 \times \text{total salary per hour}) + (\text{Jkl}^2 \times 2 \times \text{total salary per hour})$
 $= (1 \text{ hour} \times 1,5 \times \text{IDR. 57.142,85}) + (2 \text{ jam} \times 2 \times \text{IDR. 57.142,85})$
 $= \text{IDR. 314.285,67}$

b. Profit of A Project

The contractor's profit is the profit earned on a project that has a difference between the Cost Management Plan (RAB) and the Implementation Budget Plan (RAP). Profit is divided into two types, the gross profit and the net profit. Gross profit is a profit of 10% of real cost, which includes overhead costs that must be paid by the contractor. Real cost is the total cost of all work. Meanwhile, net profit is the profit obtained after incurring overhead costs during the time of implementation in the project. The real costs for the structural work in the dormitory building project is presented in table 4.1 below:

Table 4.1. Real Cost Details

No	Type of Work	Price
1	Preparation Work	IDR.53,308,533,55
2	Ground Work	IDR.126,873,826,78
3	1 st Floor Work	IDR. 1,512,750,530,34
4	2 nd Floor Work	IDR.560,003,547,71
5	3 rd Floor Work	IDR.405,037,704,36
6	4 th Floor Work	IDR.332,768,627,93
7	Floor and Roof Work	IDR.271,398,565,39
	Real Cost Detail	IDR. 3,262,141,336,06

The calculation of the amount of gross profit and net profit on the project is stated as follows:

$$\begin{aligned} \text{Gross profit} &= \text{Real cost} \times 10\% \\ &= \text{IDR. 3.262.141.336,06, -} \times 10\% \\ &= \text{IDR 326.214.133,60, -} \\ \text{Net profit} &= \text{Gross Profit - (overheadcost per day} \times \text{Implementation Time)} \\ &= \text{IDR 326.214.133,60 - (IDR 750.000,00, -} \times 119) \\ &= \text{IDR 326.214.133,60 - IDR 89.250.000} \\ &= \text{IDR 236.964.133,60} \end{aligned}$$

c. Unexpected Cost

According to the Charter Agreement (Contract), the amount of unexpected cost is 2 % of real cost. Hence, the calculation of the amount of unexpected cost on this project is stated as follows:

$$\begin{aligned} \text{Unexpected Cost} &= \text{Real cost} \times 2\% \\ &= \text{IDR Rp. } 3.262.141.336,06 \times 2\% \\ &= \text{IDR } 65.242.826,72 \end{aligned}$$

$$\begin{aligned} \text{Unexpected Cost per Day} &= \frac{\text{Unexpected Cost}}{\text{Implementation Time}} \\ &= \frac{\text{IDR. } 65.242.826,72}{119 \text{ days}} \\ &= \text{IDR } 548.259,04 \end{aligned}$$

d. Value Added Tax (VAT/Pajak Pertambahan Nilai /PPN)

According to the Charter Agreement (Contract), the cost of Value Added Tax (VAT/PPN) is 10 % of the real cost that must be paid by the contractor. Calculation of the amount of VAT/PPN cost on this project is stated as follows:

$$\begin{aligned} \text{Value Added Tax (VAT/PPN)} &= \text{Real cost} \times 10\% \\ &= \text{IDR Rp. } 3.262.141.336,06 \times 10\% \\ &= \text{IDR } 326.214.133,60, - \end{aligned}$$

Further, the overall details of indirect costs in the MTsN 1 Malang Integrated Student Dormitory building project described above is presented in table 4.2 below:

Table 4.2. Indirect Costs Details on the Structural Work

No	Type of Cost	Cost In A Day	Time	Price
1	Overhead Cost	IDR.750,00.00	119	IDR.89,250,000.00
2	Net Profit			IDR.236,964,133.60
3	Unexpected Cost	IDR. 548,259.04	119	IDR.65,22,825.76
4	Value Added Tax (VAT/PPN)			IDR.326,214,133.60

Thus, the indirect cost for the Dormitory building project is calculated into:

$$\begin{aligned} &\text{Unexpected Cost} \\ &= (\text{implementation time} \times (\text{overhead cost per day} + \text{unexpected cost per day})) \\ &\quad + \text{net profit} + \text{VAT/PPN} \\ &= (119 \text{ days} \times (\text{IDR. } 750.000,00 + \text{IDR } 548.259,04)) + \text{IDR } 236.964.133,60 \\ &\quad + \text{IDR } 326.214.133,60 \\ &= \text{IDR. } 717.671.092,96 \end{aligned}$$

4.1.2 Direct Cost of A Project

Direct Costs are costs that are directly related to project work in the field of implementation. The direct costs included in this project are labor costs and material costs. Direct costs can be obtained by increasing the real cost value minus 10% of gross profit and 2% of unexpected costs. The calculation of the amount of direct costs on the project is stated as follows.

$$\begin{aligned} &\text{Direct Cost} \\ &= \text{real cost} - \text{gross profit} - \text{unexpected cost } 2\% \\ &= \text{IDR } 3.262.141.336,05 - \text{IDR } 326.214.133,60 - \text{IDR } 65.242.825,76 \\ &= \text{IDR } 2.873.684.376,69 \end{aligned}$$

4.2 The Implementation of A Time Cast Trade Off(TCTO) Method

In order to optimize a project, in particular to the MTsN 1 Integrated Student Dormitory building project, it is necessary to accelerate some work durations situated on the critical path by applying the TCTO method. When there is a work that progressing late on the critical path then it will have an impact on the delay of the project as a whole. So, TCTO method is crucial to be applied since it needed to make an acceleration by analyzing time and cost optimization through the overtime hours on predetermined critical work.

To apply the TCTO method with alternative working hours (overtime), it is necessary to know that the normal working time is 7 hours/day (08.00 - 16.00) with 1 hour break time (13.00 - 14.00 WIB). In this case, the

work implementation will be carried out every day including normal work by means of trials starting from 1 hour to 3 hours maximum limit. As for the steps for implementing the TCTO method in calculating alternative changes to overtime hours which will be tested starting from 1 hour to 3 hours maximum limit, an example will be given for calculating 2 hours of overtime work below.

4.2.1 *Crash Duration (CD)*

Crash duration is the shortened period of time, which is the shortest time to complete a job that technically can still be accelerated. The following are the stages for calculating crash duration.

a. **Calculating The Daily Productivity**

Daily productivity can be obtained by dividing the volume of a work by the duration of the work. The following calculation is an example of calculating daily productivity for several works.

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 40 - K300 \\ \text{Daily Productivity} &= \frac{\text{Volume}}{\text{Normal Duration (ND)}} \\ &= \frac{67.82 \text{ m}^3}{13,99 \text{ days}} \\ &= 4,85 \text{ m}^3/\text{days} \end{aligned}$$

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 30 - K300 \\ &= \frac{\text{Volume}}{\text{Normal Duration (ND)}} \\ &= \frac{4.52 \text{ m}^3}{3,73 \text{ days}} \\ &= 1,21 \text{ m}^3/\text{days} \end{aligned}$$

b. **Calculating Hourly Productivity**

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 40 - K300 \\ \text{Hourly Productivity} &= \frac{\text{Daily Productivity}}{\text{Normal Working Hour}} \\ &= \frac{4,85 \text{ m}^3/\text{day}}{7 \text{ hours}} \\ &= 0,69 \text{ m}^3/\text{hour} \end{aligned}$$

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 30 - K300 \\ \text{Hourly Productivity} &= \frac{\text{Daily Productivity}}{\text{Normal Working Hour}} \\ &= \frac{1,21 \text{ m}^3/\text{day}}{7 \text{ hours}} \\ &= 0,17 \text{ m}^3/\text{hour} \end{aligned}$$

c. **Calculating the Daily Productivity After Crash**

Daily productivity after the crash is the daily productivity that occurs after the crash program is held, for each work assuming workers work in one day for 7 hours plus overtime. During overtime work, all workers attend work without(no) additional workforce. The addition of working hours (overtime) for 2 hours has a productivity reduction coefficient (e) of 0.8. The following is a daily productivity calculation after the crash for several jobs as stated below:

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 40 - K300 \\ \text{Daily Productivity After Crash} &= (\text{normal working time} \times \text{hourly productivity}) + (\text{overtime hour} \\ &\quad \times e \times \text{hourly productivity}) \\ &= (7 \text{ hour} \times 0,69 \text{ m}^3/\text{hour}) + (2 \text{ hour} \times 0,8 \times 0,69 \text{ m}^3/\text{hour}) \\ &= 5,96 \text{ m}^3/\text{day} \end{aligned}$$

$$\begin{aligned} &\text{➤ Strauss Cast Concrete } \varnothing 30 - K300 \\ \text{Produktivitas hariansesudah crash} &= (\text{normal working time} \times \text{hourly productivity}) + (\text{overtime hour} \end{aligned}$$

$$\begin{aligned}
 & \times \text{ hourly productivity)} \\
 & = (7 \text{ hour} \times 0,17 \text{ m}^3/\text{hour}) + (2 \text{ hour} \times 0,8 \times 0,17 \text{ m}^2/\text{hour}) \\
 & = 1,49 \text{ m}^3/\text{day}
 \end{aligned}$$

d. Calculating Crash Duration (CD)

Once the number of daily productivity after the crash is obtained, time needed to complete a work will be faster. The following calculation is an example of calculating the crash duration for several works, as stated below:

- *Strauss* Cast Concrete Ø 40 - K300

$$\begin{aligned}
 \text{Crash Duration} &= \frac{\text{Volume}}{\text{Daily productivity after crash}} \\
 &= \frac{67.82 \text{ m}^3}{5,96 \text{ m}^3/\text{day}} \\
 &= 11,39 \text{ days}
 \end{aligned}$$

- *Strauss* Cast Concrete Ø 30 - K300

$$\begin{aligned}
 \text{Crash Duration} &= \frac{\text{Volume}}{\text{Daily productivity after crash}} \\
 &= \frac{4.52 \text{ m}^3}{1,49 \text{ m}^3/\text{day}} \\
 &= 3,04 \text{ days}
 \end{aligned}$$

4.2.2 Normal Cost (NC)

Normal cost is the cost required to complete the work within a normal period. The steps to get this normal cost are as follows:

a. Determine The Unit Price of Worker

The following table contains data on the unit price of workers used in the MTsN 1 Integrated Student Dormitory building project originating from the company of PT. Bangun Sarana Mandiri Utama as presented in the table 4.3 below:

Table 4.3.Unit Price of Worker

No	Workforce	Amount	Price
1	Overseer/Foreman	Per day	IDR.120,000.00
2	Head of builder	Per day	IDR.100,000.00
3	Stonemason	Per day	IDR. 95,000.00
4	Worker	Per day	IDR. 75,000.00

b. Calculating the normal cost worker per hour

The normal cost of workers per hour can be obtained by multiplying the unit price of the worker's wages for each work listed in the list of unit price analysis. The following table contains a normal calculation of the cost of workers per hour for several works.

Table 4.4.Worker Unit Price According to SNI 2016

No	Workforce	Indeks	Unit	Unit Price	Total Price
1	Worker	1.650	OH	IDR.75,000.00	IDR.123,750.00
2	Builder	0.275	OH	IDR.95,000.00	IDR.26,000.00
3	Head of Builder	0.028	OH	IDR.100,000.00	IDR.2,800.00
4	Foreman/Overseer	0.083	OH	IDR.120,000.00	IDR.9,960.00
				Total	IDR.162,635.00

- *Strauss* Cast Concrete Ø 40 - K300
Normal cost of workers per hour

$$\begin{aligned}
 &= \text{Unit price of worker} \times \text{productivity per hour} \\
 &= \text{IDR. } 162.535,00 \times 0,69 \text{ m}^3/\text{hour} \\
 &= \text{IDR. } 112.647,62
 \end{aligned}$$

- *Strauss* Cast Concrete Ø 30 - K300
Normal cost of workers per hour

$$\begin{aligned}
 &= \text{unit price of worker per hour} \times \text{productivity per hour} \\
 &= \text{IDR } 162.535,00 \times 0,17 \text{ m}^3/\text{hour}
 \end{aligned}$$

= IDR. 28.161,90

c. Calculating the Normal Cost of Worker Per Day

Normal cost pekerja per hari dapat diperoleh dengan mengalikan waktu kerja normal dengan normal cost pekerja per jam. Berikut adalah perhitungan normal cost pekerja per hari untuk beberapa pekerjaan yaitu sebagai berikut

The normal cost of workers per day can be obtained by multiplying the normal working time by the normal cost of workers per hour. The following calculation is the normal cost of workers per day for several type of works:

➤ *Strauss* Cast Concrete Ø 40 - K300
Normal Cost worker per day
= Normal working time x Normal cost per hour
= 7 hours x IDR. 112.647,62
= IDR 788.533,33

➤ *Strauss* Cast Concrete Ø 30 - K300
Normal Cost worker per day
= Normal working time x Normal cost per hour
= 7 hours x IDR 28.161,90
= IDR 197.133,33

The full description from calculation of normal cost worker per day is displayed in Appendix 4 whereas the calculation of work wage costs is displayed on page 76.

4.2.3 Crash Cost (NC)

Crash Cost or cost for shortened time is the amount of cost/wage of workers needed to complete a work with an accelerated period of time (Crash Duration). The Crash Cost calculation stage can be described as follows:

a. Calculating Overtime Wages

In calculating overtime wages is referred to the Indonesia Government Regulation Number 35 of 2021 article 21 paragraph 2 which stated “for the first overtime work hour, an overtime wage of 1.5 (one and a half) times of one hour wage must be paid. Whereas for each subsequent overtime hour, an overtime pay of 2 (two) times the hourly wage must be paid.”. In this sense, the normal hourly wage is the same as the normal hourly worker cost. The following calculation is the example of how to calculate overtime pay for an overtime of 2 hours of working hour:

➤ *Strauss* Cast Concrete Ø 40 - K300
Overtime Wage per day
= (Jkl¹ x 1,5 x normal hourly wages)
+ ((Jkl² x 2 x normal hourly wages)
= (1 hour x 1,5 x IDR 112.647,62) + (1 hour x 2 x IDR 112.647,62)
= IDR. 394.266,67

➤ *Strauss* Cast Concrete Ø 30 - K300
Overtime Wage Per Day
= (Jkl¹ x 1,5 x normal hourly wages)
+ ((Jkl² x 2 x normal hourly wages)
= (1 hour x 1,5 x IDR 28.161,90) + (1 hour x 2 x IDR. 28.161,90)
= IDR 98.566,67

b. Calculating Crash Cost of Worker Per Day

The number of crash cost of workers per day can be obtained by adding the normal cost of workers per day to the overtime costs per day. The following calculation is an example of crash cost of workers per day with 2 hours overtime.

➤ *Strauss* Cast Concrete Ø 40 - K300
Crash cost of worker
= Normal cost workers per day + overtime cost per day
= IDR 788.533,33 + IDR 394.266,67
= IDR 1.182.800,00

- *Strauss* Cast Concrete Ø 30 - K300
Crash cost of worker
 = *Normal cost* workers per day + overtime cost per day
 = IDR 197.133,33 + IDR 98.566,67
 = IDR. 295.700,00

c. Calculating Crash Cost (CC)

Crash cost can be obtained by multiplying the crash cost of workers per day by the crash duration. The following is an example of calculating crash costs for several type of works

- *Strauss* Cast Concrete Ø 40 - K300
Crash Cost (CC) = *Crash Cost* worker per day x *Crash Duration (CD)*
 = IDR 1.182.800,00 x 11,39 days
 = IDR. 13.466.745,33
- *Strauss* Cast Concrete Ø 30 - K300
Crash Cost (CC) = *Crash Cost* worker per day x *Crash Duration (CD)*
 = IDR. 295.700,00 x 3,04 days
 = IDR. 897.518,27

4.2.4 Cost Slope (CS)

Cost Slope is the growth of direct costs to accelerate an activity per unit of time. The following is an example of calculating the Cost Slope for several type of works as stated below:

- *Strauss* Cast Concrete Ø 40 - K300
Cost Slope (CS) = $\frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Duration} - \text{Crash Duration}}$
 = $\frac{\text{IDR } 11.433.438,84 - \text{IDR } 10.982.766,25}{13,99 \text{ days} - 11,43 \text{ days}}$
 = IDR 967.505,44
- *Strauss* Cast Concrete Ø 30 - K300
Cost Slope (CS) = $\frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Duration} - \text{Crash Duration}}$
 = $\frac{\text{IDR } 587.486,15 - \text{IDR } 348.444,10}{3,73 \text{ days} - 3,09 \text{ days}}$
 = IDR. 373.503,20

4.3 The Implementation of Overtime Hour to the Work Project

The overtime hour description related to this study only exposed several activities whose the critical path has been determined through the Microsoft Project software program. In the following explanation, several tables of time and cost recapitulation for each overtime work hour is displayed which originated from data of MTsN 1 Integrated Student Dormitory building construction project.

Table 4.5. Example of Work Activities Overtime for Each Overtime Hour

No.	Overtime	Type of Overtime Work	Normal Duration	Crash Duration
1	1 hour	<i>Strauss</i> Cast Concrete Ø 40 - K300	13.99	11.94
2	2 hours	<i>Strauss</i> Cast Concrete Ø 40 - K300	13.99	11.39
3	3 hours	<i>Strauss</i> Cast Concrete Ø 40 - K300	13.99	10.78

According to the table 4.5, the 2 – 3 hours overtime is one of the critical activities that able to be conducted an overtime. Activities that able to get overtime will have the shortest completion time with the lowest total project cost.

The following calculation is an example of financing recapitulation for *Strauss* cast concrete work Ø 40 - K300.

Table 4.6.Financing for Each Overtime Hour

No.	Overtime	Direct Cost	Indirect Cost	Total Cost
1	Normal	IDR.2.873.684.376,69	IDR. 717.671.092,96	IDR. 3.591.360.000,00
2	1 hour	IDR.2.874.522.091,05	IDR.717.876.278,79	IDR.3.592.398.000,00
3	2 hours	IDR.2.876.121.216,32	IDR.717.119.871,88	IDR.3.593.241.000,00
4	3 hours	IDR.2.877.805.440,36	IDR.716.650.828,36	IDR.3.594.456.000,00

According to the table 4.6, an addition of 1 hour to 3 hours of overtime has meaning by the addition of overtime hours the more value will be put into direct costs, whereas the indirect cost will experience a decrease.

Table 4.7.Fastest Time Output by the Addition Cost from TCTO

No.	Overtime	Days	Acceleration	Total Cost	Cost Addition
1	Normal	119	-	IDR. 3.591.360.000,00	-
2	1 hour	118	12	IDR3.592.398.000,00	Rp. 1.038.000,00
3	2 hours	118	11.5	IDR3.593.241.000,00	Rp. 1.881.000,00
4	3 hours	117	11	IDR3.594.456.000,00	Rp. 3.096.000,00

According to the table 4.7, there are differences found in the output of time for the implementation of 1 hour to 3 hours overtime, this difference occurred due to additional costs that must be incurred for both staff and workers who involved during the overtime hours.

One type of work that underwent 1 hour overtime was the *Strauss* Cast Concrete Ø 40 - K300 work, so the time completion of this work was 118 calendar days from the normal time completion of 119 calendar days, while in terms of costs, it was IDR. 3,592,398,000.00 of the normal total cost of IDR. 3,591,360,000.00, or, in other words, there was an additional cost of IDR. 1,038,000.00.

To add to the total cost of all work, the following costs are obtained:

= normal total cost + acceleration total cost (1 hour overtime)

= IDR. 3,591,360,000.00 + IDR. 139,543,000.00

= IDR. 3,730,900,000.00

The final calculation result in an attempt to get acceleration time by employing TCTO method is an addition of working hours (overtime) for 1 hours with an optimization of 118 days from the normal completion time of 119 days, while in terms of costs, the value is IDR.3,730,900,000.00 of the normal total cost of IDR. 3,591,360,000.00, or in other words, there is an additional cost of IDR.139, 543,000.00.

V. CONCLUSION

From the result analysis by employing the Time Cost Trade Off (TCTO) method to the building project of MTsN 1 Integrated Student Dormitory in Malang city, there are several conclusions can be drawn:

1. By additional overtime hours from maximum of 3 hours, it is obtained the optimal time of 1 hour (overtime) for 7 days, and the acceleration duration for the structural work completion is 118 calendar days from the normal completion time of 119 calendar days.
2. Stages for creating a work acceleration with Time Cost Trade Off (TCTO) method are: (a) Identification of *Normal Duration* (ND), (b) Calculation of *Crash Duration* (CD), (c) Calculation of *Normal Cost* (NC), (d) Calculation of *Crash Cost* (CC) and (e) Calculation of *Cost Slope* (CS).
3. For the structural work in building project of MTsN 1 Malang Integrated Student Dormitory, the additional cost needed after having acceleration by TCTO method amounted to IDR. 3,730,900,000.00 from the normal total cost of IDR.3,591,360,000.00, or in other words, there is an additional cost of IDR. 139,543,000.00

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