

Analysis of Project Acceleration with Crashing Method on the Reability and Renovation Project Work of Iain Ambon Library

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Received: 20 Mar 2022,

Received in revised form: 14 Apr 2022,

Accepted: 24 Apr 2022,

Available online: 30 Apr 2022

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Keywords— *Project Acceleration, Crashing and
Critical Paths.*

Abstract— *The construction of a construction project often happens something that is not desirable such as the occurrence of delays in work on the project. Many factors cause delays, one way to anticipate it is by accelerating. In accelerating, the cost and quality factors must be considered, so that the optimum cost and quality are obtained according to the desired standard. The construction of the Iain Ambon Library Rehabilitation and Renovation Project was chosen for a research study due to delays in its implementation. The Critical Path Method can be used to schedule project execution time with the consideration that this method is more effective and efficient. The optimization of time and cost is obtained from the Crash Program with the Network Planning system with the Crashing method by adding accelerated working hours for each job. The acceleration is carried out on the work on the critical path with the lowest cost slope. The results of the analysis show that the total project budget under normal conditions is IDR 1,456,082,119 with a duration of 70 days, in the post-crashing condition with the alternative of adding two hours of working hours, it is IDR 2,246,877,528 or more expensive than the total project cost budget under normal conditions. and the duration of the project implementation is 51 working days or faster than the normal duration*

I. INTRODUCTION

Construction management is one of the important aspects that greatly affects the cost and time, in the implementation of a project. One aspect that is reviewed from the construction management study in terms of accelerating the implementation of work is the overtime system (increasing working hours), as well as the system for adding workers. Efficiency steps in a project are capital in work according to a predetermined schedule by determining the right equipment and using skilled and efficient costs and time in carrying out the work of a project.

Acceleration of project completion must be done with good planning. Given the limited manpower, the alternative commonly used to support the acceleration of activities is to increase working hours so that it affects the total project cost. To know this it is necessary to learn about the existing network, and the relationship between time and cost, it is called Acceleration Analysis.

In this thesis, the author conducts a case study on the IAIN Ambon Library Rehabilitation and Renovation Project Work. Which is a central government program through the Ministry of Public Works and Public Housing (Kementerian PUPR) through the allocation of DAK

APBN funds. IAIN Ambon Library Rehabilitation and Renovation Project Work This was established as a government solution in providing a suitable place to be used for students. Development IAIN Ambon Library Rehabilitation and Renovation Project Work This is expected to improve the quality of students in the field of knowledge. IAIN Ambon Library Rehabilitation and Renovation Project Work This address is at the IAIN Ambon Campus Area.

Project work delays often occur due to land disputes, material delays, weather influences. Kete Project work delays can be anticipated by accelerating attention to quality standards. Acceleration can be done by providing additional working hours, more productive tools, using materials that are faster to install, and faster construction methods.

The problem in this development project was chosen because it experienced delays in its implementation, the author will analyze the acceleration of project completion with additional working hours. The analytical method that will be used is the Crashing Method. The purpose of this method is to speed up project implementation time and analyze the extent to which time can be shortened by adding costs to activities that can be accelerated during the implementation period so that the maximum acceleration and minimum costs can be known.

II. LITERATURE REVIEW

2.1 Project Meaning

Construction project is a series of activities that are carried out only once and generally have a short period of time. A series of activities in a construction project can be divided into 2 types, namely routine activities and project activities. Routine activities are a series of continuous activities that are repeated and last a long time, while project activities are a series of activities that are carried out only once and generally in a short period of time (Ervianto, 2002).

Of a number of organizations involved in the implementation of construction projects, the role of the owner as the initiator of the project is very decisive in making decisions, formulating implementation strategies, and monitoring the progress of work implementation. Meanwhile, consultants provide services in the form of expertise, when the project owner considers that expertise is not sufficiently available in his organization. Meanwhile, the implementation of the work is usually left to the construction service provider. For this purpose, several procedures are known, one of which is a public auction.

2.2 Project Goals and Three Constraints

Dalam achieving the goals and objectives of the project that has been determined there are limitations in a project, namely Triple Constraints or three constraints consisting of:

- feea
- Watime / Schedule
- Mutu

From a technical point of view, the measure of project success is related to the extent to which these three objectives can be met. For this reason, a good arrangement is needed, so that the combination of the three is as desired, namely with project management (Soeharto, 1997).

2.3 Cost

Satu important thing in planning a project is cost. In working on a project, various types of material resources, labor, equipment and so on are needed. This will eventually involve financial problems, namely the problem of project costs and revenues as well as problems of financial receipts and expenditures.

2.3.1 Direct Cost

Direct costs are costs that arise and are directly related to ongoing project activities. Direct costs include:

a. Materials Cost

The quantity of material or material to be used must be calculated carefully by taking into account the missing material. Material costs from one place to another may differ, this is influenced by material scarcity, transportation costs and material stock.

b. Wage Cost

feea labor wages vary and depend on the skills and salary standards in which the project is located. This worker's wages include health care costs and occupational accident insurance. Project locations where the cost of living is high, the standard of salary is also high. For areas where it is quite difficult to find workers who have the required skills, it is possible to bring in workers from other areas which will increase the cost of worker mobility and the cost of lodging for workers is quite large.

c. Tool Cost

For commonly used equipment, it is necessary to consider renting or buying the equipment. Because with a proper analysis and consideration can reduce equipment costs.

d. Sub-Contractor Cost

This Fee is required if any part of the work is submitted/done by a sub-contractor. These sub-

contractors are responsible and paid for by the main contractor

2.3.2 Indirect Cost

Indirect cost is the cost required for each project activity, but is not directly related to the activity in question and is calculated from the beginning of the project to the end of the project. If the final implementation of the project is delayed from the planned time, these indirect costs will be large, while the number of jobs and the contract value remains, so that the contractor's profit will be reduced even under certain conditions will suffer losses. These indirect costs include:

1. **Overhead**
Overhead are operational costs that support the implementation of work during the project, which includes:
 - Facilities while
 - Security guard operational
 - Overhead for K3 (Kesehatan dan Keselamatan Kerja)
2. **Employee salary**
Included in this cost element are salaries and honoraria for permanent and non-permanent employees/employees involved or not involved in the project that are charged with financing the project.
3. **Unforeseen expenses**
An unexpected cost is the cost for events that may or may not occur.
4. **Profit**
The contractor's profit recommended in the work contract is generally 10% but it also depends on the magnitude of the risk of the work, the greater the risk, the greater the profit set. For contractors, profit is greatly influenced by how much efficiency the contractor concerned can do by reducing the quality, specifications and time of project implementation (Yurry Widyatmoko, 2008).

2.4 Scheduling Method

Scheduling can be defined as the time available for the implementation of each part in the context of completing a project in such a way as to achieve optimal results, taking into account the existing limitations.

the factors in the preparation of the schedule are:

1. Sasaproject run
2. Sasacompany run
3. Ketelink in another project
4. Dawhat is needed
5. Daavaiablana
6. Watime needed
7. Waavailable time
8. Hari-holiday

9. Towork overtime
10. Srequired resources
11. Savailable resources
12. Keawork force
13. Swagtask completion
14. Uwork house

2.4.1 Techniques in Scheduling

The outline of the techniques in scheduling can be grouped into:

1) **Metoda Bar Chart (Gantt Chart)**

Bar Charts were introduced by Henry L. Gantt and Frederick W. Taylor in the early 1900s. A bar chart is a list of activities arranged in vertical columns. The horizontal direction column shows the time scale. The start and end of an activity can be seen clearly, while the duration of the activity is described by the length of the bar chart.

The process of compiling a bar chart is carried out with the following steps:

- list of activity items, which contains all types of work activities in the development implementation plan.
- order of work, from the list of activity items, a sequence of work implementation is arranged based on the priority of the activity items to be carried out first and the activity items to be carried out later, without ruling out the possibility of concurrent execution of the work.
- Work execution time is the implementation period of all activities calculated from the beginning of the activity until the end of all activities. Work execution time is obtained from the sum of the time required to complete each activity item.

The advantages and benefits of bar charts include:

1. Before its graphics and easy to understand by all levels of management, so it can be accepted and used in the implementation widely.
2. It is a good planning and scheduling tool, requiring only a few refinements (revisions) and updates than sophisticated systems.

While the limitations and weaknesses of bar charts include:

1. the relationship between each activity can not be seen clearly.
2. Diagram rods are not adequate for use in surveillance work, because the activities that determine the speed of time are not clearly visible.

3. Alternatives to improve the schedule for the implementation of other activities cannot be read in the bar chart. ----->
4. if there are one or several activities experiencing delays, then the overall picture is difficult to know exactly to what extent this will affect the overall project schedule

No.	Job Order	Week												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Foundation work	█	█	█	█									
2	Concrete works	█	█	█	█	█	█							
3	Kap's job							█	█	█	█			
4	Attic Work										█	█	█	
5	Plastering Work					█	█	█	█					
6	Floor job			█	█	█	█	█						
7	Door work									█	█			
8	Painting Work						█	█	█	█				
9	Equipment Work						█	█	█	█	█			

Fig.1: Example of a Bar Chart (Gantt Chart) (Yurry, 2008).

2) CPM Method (Critical Path Method)

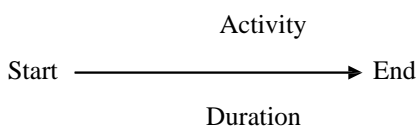
In this method the work (activity) is represented by two arrows, while the node as a marker of the start and end of a job. The relationship between activities is possible only in the form of a finish to start relationship. In this method, there is a "dummy" which is a facility that can be considered as an activity that has no duration.

CPM is a planning technique based on a network developed from a research effort initiated in 1956 by the engineering services department of the company E.I du pont de memoirs. According to CPM, most of the work can be reduced in execution time, if human resources, machines, money and so on are added to its implementation.

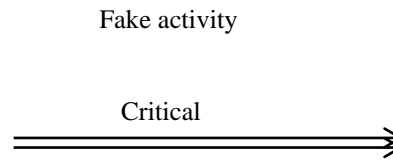
if this condition is more favorable then the time of completion of the work must be advanced. On the other hand, if there is no reason to shorten a job, the work has a slack of execution time (float), then the work must be carried out normally or normally.

Here are 3 terminology on the arrow diagram:

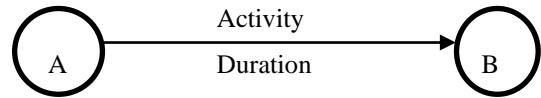
1. Real activity



2. Fake activity



3. Incident



how much terminology is in the arrow diagram, including:

- **Real activity**
A Real activity is the implementation of real activities from a job, so it requires human resources, materials, equipment, and other facilities. Real activity is described by grafis as arrows on the network and the duration of the process is included. Examples are concrete reinforcement work, concrete mold making work, and concrete casting work.
- **False Activity**
A False activity is also known as dummy activity and is represented as a dotted arrow. Dummy activities are no different from real activities insofar as they are involved in the logic of the network and should always be required as activities without the dimensions of time and resources.
- **Events**
Kejadian is the starting point and point end of an activity. An event does not require time or resources. Graphically, the event is depicted as a circle with a number coded in it and symbolized by an arrow drawn in a straight line and may be broken.

3) Critical Path

To determine activities that are critical, and then determine the critical path, forward calculations and backward calculations can be carried out. Forward calculations are carried out to get the Earliest Start (ES) and Earliest Finish (EF) which are called predecessors. The backward calculation is carried out to get the latest start (LS) and latest finish (LF) which are called successors.

Critical path is characterized by the following conditions:

1. Earliest Start(ES) = Latest Start (LS)
2. Earliest Finish(EF) = Latest Finish (LF)
3. Latest Finish(LF) – Earliest Start (ES) = Activity duration
4. Early Start- the time when all previous tasks were completed

5. *Early finish*- closest start time and time required to complete the task
6. *late finish*- all activities completed without delaying the deadline
7. *Late start*- The last ending time minus the time it took to complete the task.

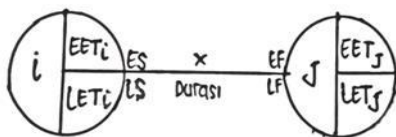
4) float

Floats is the amount of time available in an activity that allows the activity to be delayed or delayed intentionally or unintentionally, but the delay does not cause the project to be delayed in its completion. There are two types of floats, namely total floats and free floats. (Ervianto, 2002).

Total float is the amount of time available for delays or delays in the implementation of activities without affecting the completion of the project as a whole.

Free float is the amount of time available for delaying or delaying the implementation of activities without affecting the start of activities that immediately follow them. (Ervianto, 2002)

Independent Float is the number of delays that can be assigned to each activity without delaying the next activity or limiting the scheduling of the previous activity. Independent Float, (Ifij) for activities (i, j).



2.5 Accelerate Project Completion Time

Accelerate project completion time is an attempt to complete the project earlier than the completion time under normal circumstances. With the acceleration of this project, there will be a reduction in the duration of the activities that will be held for the crash program. The maximum crash duration of an activity is the shortest duration to complete an activity that is technically still possible assuming the resource is not a bottleneck. The duration of the maximum acceleration is limited by the project area or work location, but there are four factors that can be optimized to accelerate an activity, which include increasing the number of workers, scheduling overtime work, using heavy equipment and changing construction methods in the field. (Ariany, 2010).

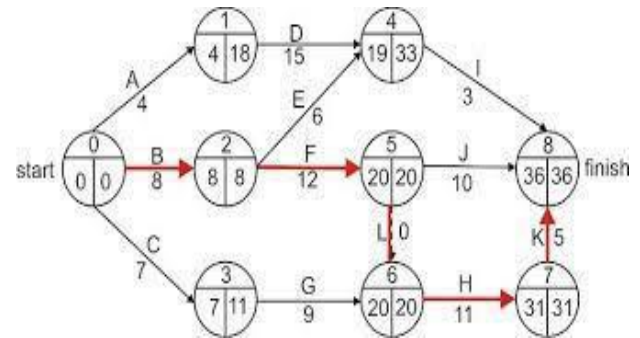


Fig.2: Example of critical path

2.5.1 Additional Working Hours (Overtime)

Speeding up the implementation time of an activity by adding working hours or working overtime is one of the efforts to increase work productivity so that it can speed up the implementation time of an activity. The overtime work plan is:

- Normal working time is 8 hours (08.00 – 17.00), while overtime work is done after normal working time.
- pricea. wages of workers for overtime work according to the Decree of the Minister of Manpower Number KEP.102/MEN/VI/2004 article 11 concerning Overtime Work and Overtime Wages:
 - for the first 1 hour of overtime work is 1.5 (one and a half) times the hourly wage.
 - For each subsequent hour of overtime work must be paid 2 (two) times the hourly wage.

DaFrom the description above can be formulated as follows

Overtimefee per day = (first hour of overtime x 1.5 x normal hourly wage) + (next hour of overtime work x 2 normal hourly pay).

Table.1: Coefficient of Productivity During Overtime

overtime hours (hours)	Productivity Index Decrease	Performance (per hour)	Percentage of Work Performance (%)	Productivity Reduction Coefficient
a	b	c=b*a	d	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: Fredrika, Ariany. 2010)

2.6 Understanding Crashing

Crashing is a deliberate, systematic and analytic process by testing all activities in a project centered on activities that are on the critical path. The crashing process is done by estimating the variable costs in determining the maximum and most economical reduction in the duration of an activity that is still possible

to be reduced. This process seems simple, but is in fact very complex. There are various ways to reduce the duration of a project and many combinations of activity duration and cost must be considered in a detailed analysis.

2.6.1 Process Crash

Speeding up the implementation of a project must be designed in advance. This can result in a good duration acceleration. It is necessary to pay attention to balance in the design, even though it may be with the consequence of increasing human resources. But as long as adding human resources is still cheaper than extra payments due to project delays, then the addition of human resources can be taken into account.

Generally, when the execution time of a job is shortened (crashing), the direct costs will increase. Planning based on the lowest direct cost is not necessarily the best, because it is synonymous with a long time, even though the total cost of the project, including indirect costs, also affects the implementation time.

Accelerating the duration of an activity will increase costs, but will not necessarily shorten the overall project time, unless the activity is a critical activity. That is why we need the best combination of activities that accelerate the duration of their implementation in producing the most economical project time, where our goal is to complete a technical and economical project requires a careful calculation to where we can shorten the time by adding the smallest possible cost. .

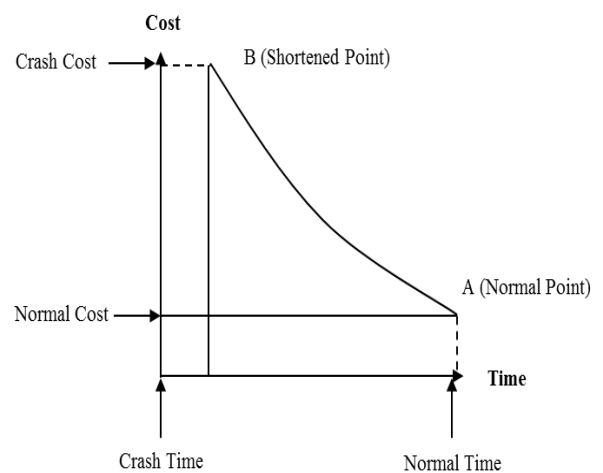
Activities in a project can be accelerated in various ways, namely:

- By holding work shifts, it means additional costs in the form of costs for lighting, meals and so on.
- By extending working time (overtime).
- By using more productive tools.
- Increase the number of workers.
- By using materials that can be installed faster
- Using another construction method which is faster.
- Subcontracting an activity.

To implement the use of multiple shifts in the work is more suitable if the duration set by the project owner is very short. However, so that the set duration is quite reasonable, this should be avoided. Because if you do a shift, you have to consider various things, such as lighting, support services, safety and productivity. Usually with the use of shifts, the costs incurred will exceed the budget plan set for the use of facilities for work services and decrease worker productivity. So, it can be said that the use of shifts in a job will increase the costs that must be incurred. However, it can dramatically

reduce or reduce the duration of work up to 50% of the set duration (Tarore and Mandagi, 2006). Extending work time helps reduce the overall time of an activity. Workers are employed up to 10-12 hours/day, this can reduce the duration of an activity by up to 33%. Additional costs for providing work service facilities as well as declining productivity of workers continue to occur. The most common method used to shorten project duration is assigning additional labor and equipment to each activity. However, it also has advantages and disadvantages. The speed gained, however, remains limited even if adding more workers doubling the size of the workforce will not reduce project completion time by half. Additional costs for providing work service facilities as well as declining productivity of workers continue to occur. The most common method used to shorten project duration is assigning additional labor and equipment to each activity. However, it also has advantages and disadvantages. The speed gained, however, remains limited even if adding more workers doubling the size of the workforce will not reduce project completion time by half. Additional costs for providing work service facilities as well as declining productivity of workers continue to occur. The most common method used to shorten project duration is assigning additional labor and equipment to each activity. However, it also has advantages and disadvantages. The speed gained, however, remains limited even if adding more workers doubling the size of the workforce will not reduce project completion time by half.

To further analyze the relationship between costs and the time of an activity, several terms are used, namely: normal period / Normal Duration (ND), shortened period / Crash Duration (CD), Normal cost / Normal Cost (NC), and Cost for time. shortened/Crash Cost (CC). Below is a graph of the normal and abbreviated time-cost relationship for an activity.



Gbr.3: Graph of normal and shortened time-cost relationship for an activity (Soeharto, 1997)

On Figure 3 point A shows the normal point, while point B is the shortened point. The line connecting point A with B is called the time-cost curve. In general, this line can be considered as a straight line, if not (for example, concave) then the calculation of a segment consisting of several straight lines is carried out. If you know the shape of the time curve for the cost of an activity, it means that by knowing what the slope or angle of inclination is, you can calculate how much it will cost to shorten the time of one day.

The additional direct cost of accelerating an activity per unit time is called the cost slope.

The cost slope formula is as follows:

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

2.6.2 Cost-Time Relationship

The total project cost is the sum of the direct costs and indirect costs used during project implementation. The amount of this cost is highly dependent on the length of time (duration) of project completion, both of which change according to the time and progress of the project. Although it cannot be calculated by a certain formula, in general, the longer the project runs, the higher the cumulative indirect costs required. Figure 4 shows the relationship of direct costs, indirect costs and total costs in a graph and it can be seen that the optimum cost is obtained by finding the smallest total project cost.

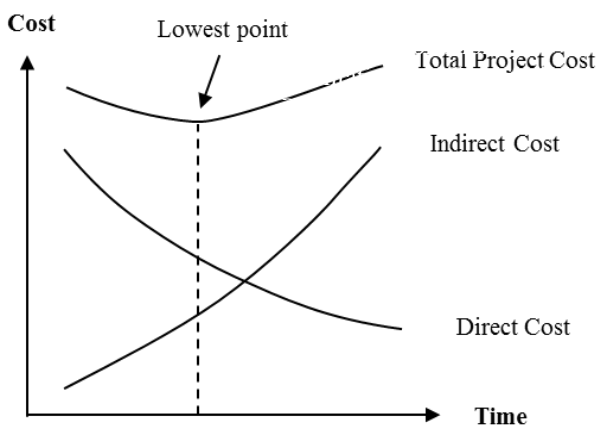


Fig.4: Graph of the relationship of time with total costs, direct costs, and indirect costs (Soeharto, 1997)

The procedure for shortening the time is described as follows:

1. calculate project completion time and identify floats using normal timeframes.
2. determine the normal cost of each activity.
3. determine the accelerated cost of each activity.
4. calculate the cost slope of each component of the activity.

5. shorten the period of activity, starting with the critical activity that has the lowest cost slope.
6. Billa in the process of accelerating the project time a new critical path is formed, then accelerate the critical activities that have the lowest combination of cost slopes.
7. continue to shorten the activity time until the project point is shortened
8. Tabulate the cost versus time, plot it in a graph and connect the normal points (normal cost and time), the points that are formed each time the activity shortens, up to the TPD points (Shortened Project Points).
9. HitTake the indirect costs of the project and depict them in the graph above.
10. Add up direct costs and indirect costs to find the total cost before the desired timeframe.
11. Check the total cost graph to achieve the optimal time, namely the project completion period with the lowest cost (Soeharto, 1997).

III. METHODOLOGY

3.1. Research sites

This case study was conducted on the IAIN Ambon Library Rehabilitation and Renovation Project which is located in the Ambon City IAIN Ambon Campus Area. PT. Laleva Indah Lestari who is the Executing Contractor.



Fig.5: Research Site Map

3.2. Data collection technique

To obtain data that can be verified, relevant, and complete, then the author uses a method or technique in collecting the data. The data collection methods used in this research are

1. Field Observation

Field Observation intake was carried out to obtain primary data by conducting a direct survey on the IAIN Ambon Library Rehabilitation and Renovation Project Work which became the object of research, namely to obtain information or documentation through interviews with implementing contractors, and workers at the project site and related parties in the room. the scope of the project. Project documentation and project data archives obtained from the contractor, namely PT. Laleva Indah Lestari

2. Literature Study

Studiesbibliography is carried out to obtain secondary data to support the primary data obtained. This secondary data collection was carried out by reading and studying books, lecture notes, browsing the internet and journals related to the problem of implementing additional working hours and labor in the IAIN Ambon Library Rehabilitation and Renovation Project Work.

3.3. Data Type

The types of data used in this writing are:

1 Primary data

Represents data that can only be obtained from the original or first source. This primary data is formenget information or documentation of the project work process to be observedin the form of interviews with parties involved in project implementation such as the components of indirect costs and the causes of delays in implementation

2 Secondary Data

Secondary data is data that is already available obtained from the relevant agencies as follows:

- a) S . curve
- b) Budget plan
- c) Price list for wages and materials
- d) Shop Drawing

3.4. Data source

The data obtained for this writing is sourced from the library method, journals and documents from the project planner.

3.5. Research Stages

The stages that need to be carried out in this research are as follows:

- 1. Secondary data collection.
- 2. Network Diagram Preparation

The steps for compiling a network diagram are:

- Define / describe each work item
- Determine interrelated activities, activities that precede other activities (predecessors)

- Compile the duration of each work item based on the scheduling data of each activity
 - Determine the critical path
3. Calculate the normal cost of each activity
 4. Implementing Crashing Scenarios

3.6. Research Flowchart

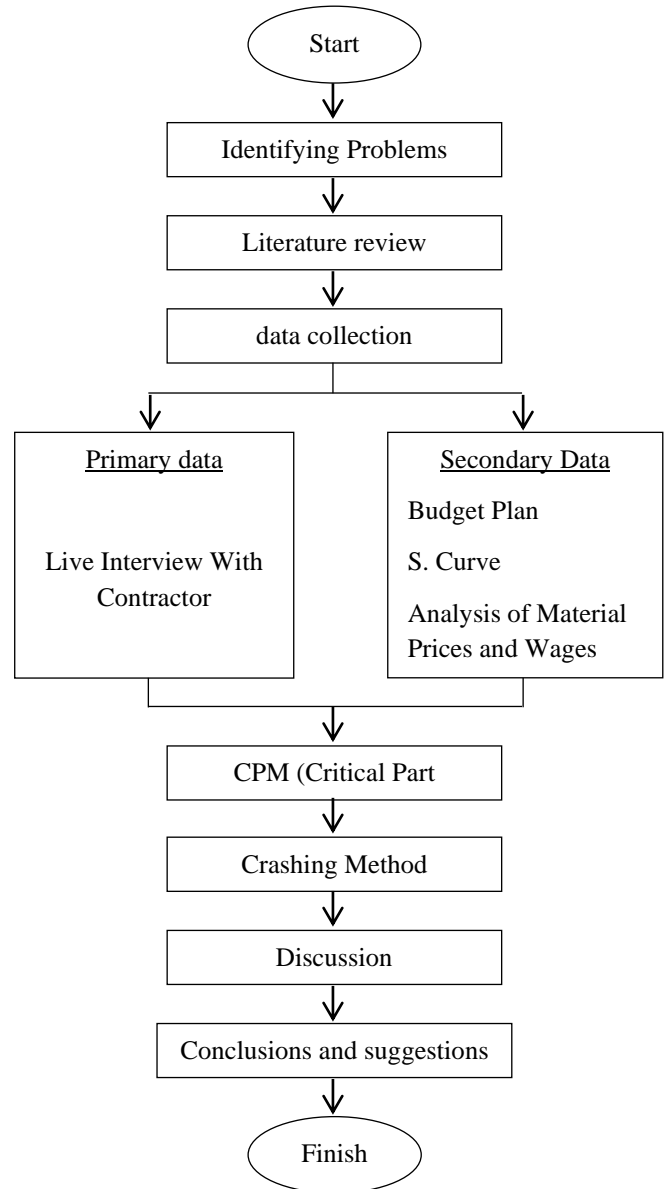


Fig.6: Research Flowchart

IV. ANALYSIS AND DISCUSSION

4.1. Project Data

The project used as a case study in this research is the IAIN Ambon Library Rehabilitation and Renovation Development Project, which is located at the Ambon City IAIN Campus Area, Ambon City. This project was chosen as a case study in this research because its

implementation was delayed, so it was necessary to accelerate so that the project could be completed on time or even faster than the normal duration of planning. In this study, only activities that are accelerated on the critical path are accelerated. The project data are as follows:

1. Project name : Rehabilitation Development and IAIN Ambon Library Renovation
2. Property of Project : PUPR Service
3. Pelike Project : PT. Anugrah Putra Perkasa Jo PT. Laleva Indah Lestari
4. Project plans : CV. Data Teknik
5. Supervise Project : PT. Bintang Perkasa Sejati Jo CV. Pesona Consultant
6. Project Location : IAIN Ambon City Campus Ambon
7. Project Duration : 70 calendar days
8. Source of funds : DAK APBN 2020

4.2. Determination of the Critical Path using CPM

In calculating the Critical Part Method (CPM), the job description, activity code, and duration must first be determined which can be seen in the table below.

Table.2: Jobs on the Critical Path

No.	Job description	Activity Code	Normal Duration (Day)
1	Termite work	A	7
2	K1. Column Work	B	21
3	B1. beam work	E	14
4	G1. beam work	F	14
5	Floor Plate Work Elev+0.00 S2	I	14

(Source: Analysis Results)

Table.3: Dependency Calculation

ACT.	DUR	ES	EF	LS	LF	TF	FF	DESC.
A	7	0	7	0	7	0	0	Critical
B	21	7	28	7	28	0	0	Critical
C	14	7	21	28	42	21	0	Non Kritis
D	7	28	35	35	42	7	0	Non Critical
E	14	28	42	28	42	0	0	Critical

F	14	42	56	42	56	0	0	Critical
G	14	35	49	42	56	7	0	Non Critical
H	14	21	35	42	56	21	0	Non Critical
I	14	56	70	56	70	0	0	Critical

(Source: Analysis Results)

4.3. Accelerate Duration By Adding Working Hours

The productivity of each worker per day has been known from the previous analysis with a normal working hour duration of 8 hours/day. So that the duration of crashing will be calculated by adding two hours of work per day by considering the decrease in labor productivity during overtime hours.

Calculation of Crashing Duration on termite-proof work that is on the Critical path is as follows:

$$\begin{aligned} \text{Normal Daily Productivity} &= \frac{\text{volume}}{\text{normal normal}} \\ &= \frac{1 \text{ m}^3}{7 \text{ hari}} \\ &= 0.14 \text{ m}^3/\text{day} \end{aligned}$$

$$\begin{aligned} \text{Productivity per hour} &= \frac{\text{daily productivity}}{\text{working hours}} \\ &= \frac{0.14 \text{ m}^3/\text{day}}{8 \text{ jam}} \\ &= 0.02 \text{ m}^3/\text{hour} \end{aligned}$$

$$\begin{aligned} \text{Overtime productivity} &= 2 \times \text{Productivity per hour} \times 0.80 \\ &= 2 \times 0.02 \text{ m}^3/\text{hour} \times 0.80 \\ &= 0.03 \text{ m}^3/\text{hour} \end{aligned}$$

$$\begin{aligned} \text{Daily productivity acceleration} &= \text{Normal daily productivity} + \text{Overtime hours} \\ &= 0.14 \text{ m}^3/\text{day} + 0.03 \text{ m}^3/\text{day} \\ &= 0.17 \text{ m}^3/\text{day} \end{aligned}$$

$$\begin{aligned} \text{Crash duration} &= \frac{\text{volume}}{\text{productivity after crash}} \\ &= \frac{1 \text{ m}^3}{0.17 \text{ m}^3/\text{days}} \\ &= 6 \text{ days} \end{aligned}$$

4.4. Calculation using the crashing method

In accelerating the duration of the project, it is usually carried out on jobs that have a critical path. Because the activities that have a major influence on the project on the critical path.

The stipulations on the plan for the alternative of adding working hours are as follows:

1. Normal working time is 8 hours of work per day (08-00-17.00) with 1 hour (12.00-13.00), while overtime work is done after normal working time of 2 hours per day (18.00-20.00).
2. In the decision of the Minister of Manpower Number KEP.102/MEN/VI/2004 article 3, article 7 and article 11 the standard overtime pay is:
 - a. Overtime work can only be done for a maximum of 4 (four) hours in 1 (one) day and 14 (fourteen) hours in 1 (one) week.
 - b. Provide food and drinks of at least 1,400 calories if overtime work is carried out for 3 hours or more.
 - c. For the first overtime work must be 1.5 times the hourly wage.
 - d. For each subsequent hour of overtime work must be paid wages equal to 2 times the wages of 1 hour.
3. Productivity for overtime hours can be seen in table 1.

4.4.1 Daily, Normal and Accelerated Productivity Calculation

Accelerated daily productivity is obtained from the number of normal daily productivity with work productivity during overtime hours per day. The addition of overtime hours according to applicable regulations is carried out for 2 hours per day, while the productivity of overtime workers has decreased and is calculated at 80% of the productivity of regular working hours.

For more details on the amount of labor wages in this project, see the following table:

The steps for calculating daily productivity for critical work acceleration are as follows:

- a. Calculating the volume of work
- b. Calculating normal duration
- c. Calculating normal daily productivity
- d. Calculating normal cost
- e. Normal productivity/hour
- f. Overtime productivity
- g. Accelerated daily productivity

Example :

Calculation of normal daily productivity onTermite work

- | | |
|------------------------------|--|
| a. Job volume | = 1 m3 |
| b. Unit price | = IDR. 5,000,000 |
| c. Normal Duration | = 7 days |
| d. Normal Cost | = unit price × volume
=IDR 5,000.00 × 1 m3
= IDR 5,000,000 |
| e. Normal daily productivity | = $\frac{\text{job volume}}{\text{Normal Duration}}$ |

- | | |
|-----------------------------------|---|
| | = $\frac{1 \text{ m3}}{7 \text{ Day}}$
= 0,14 m3/day |
| f. Normal productivity/hour | = $\frac{\text{Normal daily productivity}}{\text{normal working time}}$
= $\frac{0,14 \text{ m3/day}}{8 \text{ Hour}}$
= 0,02 m3/hour |
| g. Overtime productivity | = 2 × normal productivity/hour × 0.80
= 2 × 0.02 m3/h × 0.8
= 0.03 hours |
| h. Accelerated daily productivity | = daily normal productivity + overtime productivity
= 0.143 m3/day + 0.029 m3/hour
= 0,17 hours |

4.4.2 Calculation of Crash duration, Crash cost, and Cost slope

After knowing the daily productivity of critical work acceleration, the next step is to calculate the duration of the acceleration (crash duration) and the direct cost of acceleration (crash cost). This crash duration calculation is used to get the maximum time limit for an activity to be able to crash. While the crash cost calculation is used to find the cost slope of each activity.

To determine the Crash cost can be done with the following steps:

- a. Calculating normal daily wages, i.e. daily productivity × price of one working wage
- b. Calculating normal work wages, i.e. productivity per hour × unit price of work wages
- c. Calculating overtime work per day
For 2 hours of overtime = (1.5 × normal hourly wage) + 2(2 × normal hourly wage)
- d. Calculating crash cost per day, i.e. daily wage acceleration × crash duration

An example of calculating crash duration for an Anti-Termite job that is on a critical path is as follows:

Anti termite work

- | | |
|-----------------------------------|--|
| a. Normal cost | =IDR 5,000,000 |
| b. Normal duration | = 7 days |
| c. Normal productivity/day | =0.143 days |
| d. Normal productivity/hour | = 0.02 hours |
| e. Productivity overtime/hour | = 0.029hours |
| f. Accelerated daily productivity | = 0.017m2/day |
| g. Crash Duration | = $\frac{\text{job volume}}{\text{daily productivity acceleration}}$
= $\frac{1.00}{0,017}$
= 6 days |
| h. Normal wage/hour | =unit price × normal productivity/hour |

$$\begin{aligned}
 &= \text{IDR } 5.000.000 \times 0,02 \\
 \text{hours} &= \text{IDR } 90,000 \\
 \text{i. Normal wage/day} &= \text{normal wage/hour} \times 8 \\
 \text{hours} &= \text{IDR } 90,000 \times 8 \text{ hours} \\
 &= \text{IDR } 720,000 \\
 \text{j. Wage 2 hours overtime/day} &= (1.5 \times \text{normal wage/hour}) + 2 \times (2 \times \text{normal wage/hour}) \\
 &= (1.5 \times \text{IDR } 90,000) + 2 \\
 &= \text{IDR } 495,000 \\
 \text{k. Acceleration fee/day} &= \text{normal wage/day} + 2 \\
 &\text{hours overtime wages} \\
 &= \text{IDR } 720,000 + \text{IDR } 495,000 \\
 &= \text{IDR } 1,215,000 \\
 \text{l. Crash cost} &= \text{acceleration wage/day} \times \\
 &\text{crash duration} \\
 &= \text{IDR } 1,215,000 \times 6 \text{ days} \\
 &= \text{IDR } 7,290,000.00 \\
 \text{m. Cost Slope} &= \frac{\text{crash cost} - \text{normal cost}}{\text{Normal Duration} - \text{Crash duration}} \\
 &= \frac{\text{IDR } 7.290.000 - \text{IDR } 5.000.000}{7 - 6} \\
 &= \text{IDR } 2,290,000.00
 \end{aligned}$$

Table.4: Calculation results of crash duration, crash cost and cost slope

Job description	Normal	Normal Cost (IDR)	Crash	Crash Cost (IDR)	Cost Slope (IDR)
Termite Work	7	5,000,000	6	7,290,000	2,290,000
1 floor structure					
K1. Column Work	21	145,994,542	14	169,907,441	11.007.525
B1. Beam Work	14	109,582,798	7	166.221.098	.87,737,128
G1. Beam Work	14	245,464,482	12	345,184,427	130,731,566
Floor Plate Work Elev+ 0.00 S2	14	177.211.607	12	303,169,791	140,855,650

(Source: Analysis Results)

4.5. Cost Analysis

After completing the acceleration analysis process and getting the duration of the acceleration, it will then calculate the total and project costs under normal conditions and in conditions after acceleration. The total cost of the project consists of direct costs and indirect costs as follows:

Project duration : 70 calendar days

Total project cost : IDR 1,456,082.119

$$\begin{aligned}
 \text{a. Profit} &= \text{Total project cost} \times 10\% \\
 &= \text{IDR } 1,456,082,119 \times 10\% \\
 &= \text{IDR } 145,608,212 \\
 \text{b. Overhead costs} &= \text{Total Project cost} \times 5\% \\
 &= \text{IDR } 1,456,082,119 \times 5\% \\
 &= \text{IDR } 72.804.106 \\
 \text{c. Overhead per day} &= \frac{\text{feea overhead}}{\text{Normal Duration}} \\
 &= \frac{72.804.106}{70 \text{ days}}
 \end{aligned}$$

$$= \text{IDR } 1,040,059$$

After getting the value of profit and overhead costs, then the next step is to calculate the direct costs and indirect costs.

Normal Condition

$$\begin{aligned}
 1. \text{ Direct cost} &= 85\% \times \text{total project cost} \\
 &= 85\% \times \text{Rp. } 1,456,082.119 \\
 &= \text{IDR } 1,237,669,801 \\
 2. \text{ Indirect costs} &= \text{profit} + \text{overhead cost} \\
 &= \text{IDR } 145,608,212 + \text{IDR } 72.804.106 \\
 &= \text{IDR } 218,412,318 \\
 3. \text{ Total cost} &= \text{Direct Cost} + \text{Indirect Cost} \\
 &= \text{IDR } 1,237,669,801 + \text{IDR } 218,412,318 \\
 &= \text{IDR } 1,456,082.119
 \end{aligned}$$

Crash Condition

$$\begin{aligned}
 1. \text{ Direct cost} &= \text{normal cost} + \text{total cost slope} \\
 &= \text{Rp. } 1,237,669,801 + \text{Rp. } 611,905,321
 \end{aligned}$$

$$= \text{Rp}1,849,575,122$$

2. Indirect costs = (crashing duration × overhead per day) + profit

$$= (51 \times \text{IDR } 1,040,059) + \text{IDR } 145,608,212$$

$$= \text{IDR } 198,651,203$$

3. Total cost after crash = direct cost + indirect cost

$$= \text{IDR } 1,849,575,122 + \text{IDR } 198,651,203$$

$$= \text{IDR } 2,048,226,325$$

Table.5: Smallest to Largest Cost Slope

ID	JOBDESCRIPTION	NORMAL DURATION	CRASH DURATION	COST SLOPE (IDR)
1	TERMITE WORK	7	6	2,290,000
2	K1. COLUMN WORK	21	14	11.007.525
3	B1. BEAMWORK	14	7	87,737,128
4	G1. BEAMWOK	14	12	130,731,566

7	FLOOR PLATE Elev+0.00 S2	14	12	140,855,650
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(Source: Analysis Results)

Table.6: Comparison of Project Duration and Costs

	Duration (Days)	Direct Cost (IDR)	Indirect Cost (IDR)	Total Cost (IDR)
Normal Project	70	1,237,669,801	218,412,318	1,456,082.119
Accelerated Project	51	2,048,226,325	198,651,203	2,246,877,528
Difference	19	810,556,524	19,761.114	790,795,409

(source: Analysis Results)

Table 5 shows that the shorter the project duration, the greater the direct costs and indirect costs decreased. The total cost is obtained from the sum of the direct and indirect costs.

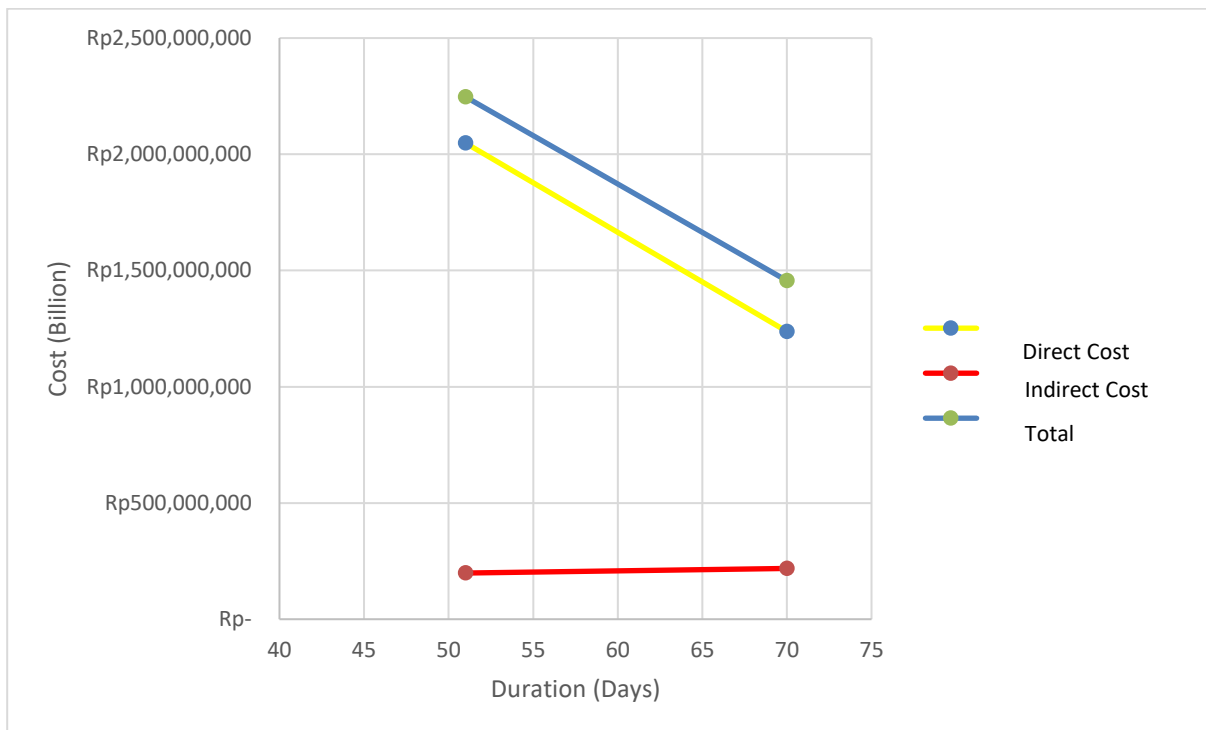


Fig.5: Time-Cost Relationship Graph

From the analysis above, the crashing time is 51 days with an acceleration time of 19 days from the normal 70

days, with a direct cost of Rp.2,048,226,325 and the indirect costs are Rp198,651,203. Accelerated project

duration not only affects direct costs but also indirect costs under normal conditions. This effect causes a decrease in indirect costs of Rp19,761.114 and an additional direct cost of Rp.790,795,409

V. CONCLUSIONS AND SUGGESTIONS

5.1. Conclusions

Based on the results of the analysis and discussion, this study can draw the following conclusions:

1. After accelerating the duration, the duration obtained when accelerating is 51 working days from the normal duration of 70 working days
2. The total cost of the project under normal conditions is IDR 1,456,082,119 with a project implementation duration of 70 working days. From the results of the analysis in this study, the total cost of the project in post-crashing conditions with the alternative of additional working hours for 2 hours was IDR 2,246,877,528 or more expensive than the project cost under normal conditions and the duration of project implementation was 51 working days or faster of normal duration.
3. The critical steps in the IAIN Ambon Library Rehabilitation and Renovation development project using the CPM Method are Termite Anti-termite Work, K1. Column Work, B1. Beam Work, G2. Beam Work, G3. Beam Work, Floor Plate Work Elev+4.00 S1 and Floor Plate Work Elev + 0.00 S2

5.2. Suggestions

Based on the results of the research that has been done and the conclusions above, the authors provide the following suggestions:

1. When there is a delay, it should be accelerated by speeding up work on the critical path to make it more efficient. Acceleration can be in the form of adding overtime hours, adding tools, adding work groups, or by working shift.
2. This study only analyzes the time and cost of structural work, so for further research, this research would be better if time and cost analysis were carried out on all project work items, both architectural work, mechanical work and electrical work.

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