Network Planning Analysis Using The Critical Path Method (CPM) as an Evaluation Tool for Project Planning and Control (Case Study of a Residential House Development Project in Pare City, Kediri Regency)

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ABSTRACT

The construction of residential houses in Pare City Kediri Regency experienced problems in the construction process was late from the predetermined schedule, which resulted in increased costs incurred. This project is located in Pare City, Kediri Regency, on a land area of 1200 M² with a size of 120 x 10 M first construction is a 20 x 8 M residential house. According to the agreed plan and a master schedule, this project is expected to be completed within 80 working days, and every day only work for 8 hours reality the implementation of this project, various factors affect the progress of the work. The percentage of actual cumulative progress until the 4th week of January is 97.42% of the 100% master schedule plan, there is a deviation of 2. 58 & it can be seen that the achievement of progress from the previous month indicates a continuous delay from the monthly plans made. One of the methods that must be used to design Network Planning is the Critical Path Method (CPM). The CPM method is used to plan, schedule, and control project activities that are deterministic or single time after evaluation data is obtained so that time and cost are more efficient and effective in calculating evaluation data using the CPM method. The project, which was initially completed in 103 days at Rp. 213,956,500 after being evaluated, and if there were no mistakes during project implementation, the normal time was 72 days at Rp. 160,276. 500 and then using the CPM method obtained an effective time of 52 days and an efficiency cost of Rp. 115,755,240.

Keywords: *Critical path method (CPM), Network Planning, Acceleration, Time, Cost.*

Received: 22 Mei 2023; Revised form: 15 Juli 2023; Accepted: 02 Agustus 2023; Online: 30 November 2023
2527-9947/© 2023 The Authors. DOI: 10.30996/jem17.v8i2.9905

Published by Fakultas Ekonomi dan Bisnis, Universitas 17 Agustus 1945 Surabaya.

INTRODUCTION

The project is a combination of interrelated activities that must be carried out following the flow of activities until the goal is achieved. Each project has an activity deadline where the project must be completed before or according to a predetermined duration and cost. Projects have unique characteristics that one to another will not be the same, so each outcome project.

The cause of the failure of a project is the lack of planning, scheduling, and control so that activities on construction projects are inefficient and result in the quality of the work decreasing, budget costs exceeding plans, and time exceeding the normal schedule. Work delays are a problem that often occurs in project implementers. These delays can be caused by weather factors, changing conditions at the work location, or delays in material supply.

This study analyzes the important aspects of Network Planning, scheduling, and control. Network Planning is the relationship between project activities shown in the form of workflow. Through this workflow, information is obtained about the activities to be carried out so that it is easier to understand (Anggraeni, 2017). By considering various methods in Network Planning, in the case of Pak Rudi's residential development project, the author will use the Critical Path Method (CPM) method to evaluate the planning, scheduling, and control of work activities on the housing construction of the project in Pare City Kediri Regency experienced significant delays in time and financing.

Formulation of The Problem

There are several problem formulations in this study which consist of the following:

1. Does the execution of projects employing CPM to construct homes produce prompt and economical results?
2. What causes the delays in housing construction projects in Pare City, Kediri Regency?

Writing Purposes

The research objectives to be achieved in writing articles include the following:

1. Knowing whether using the CPM method on a house construction project in Pare City Kediri Regency will result in an effective time and cost-efficient approach.
2. Knowing the causes of delays in housing construction projects in Pare City, Kediri Regency

LITERATURE REVIEW

Project Management

Network Planning is the relationship between project activities shown in the form of workflow. There should be careful planning with various option obstacles needed as a reference in carrying out work activities so that the project can be carried out. CPM is a method and analysis for planning, controlling, and scheduling project activities that are deterministic or single-time. This critical path is used knowing activities that affect the speed or slowness of a project.

The critical path starts from the initial activity to the activity of a project. By considering the various methods in Network Planning, in the case of Mr. Rudi's residential project, the author will use the Critical Path Method to evaluate the planning, scheduling, and control of work activities on the housing construction project in Pare City, Kediri Regency, which has experienced delays in time and expensive financing. Every company or organization carrying out its activities must face obstacles that will

hinder the achievement of company or organizational goals corporation to achieve maximum results in achieving its goals requires a system called management. The definition of management according to T. While the understanding of management according to Vernon A. From the above, it can be concluded that management is a process of planning, directing, organizing, and controlling carried out by a company or an organization toward the efforts of its members and the use of resources to achieve the goals that have been planned. There are various management sciences, one of which is Operational Management.

Project Activity Engineering

In carrying out a project, there are 3 project management constraints called the triangle project constraint.

Scope

It is essential to define the scope or area of a project to register everything that is a component. This will help your efforts and resources be spent more wisely.

Cost

In the triple constraint, costs describe cost constraints (budget). Many factors influence this cost calculation, from paying the people working on the project to unforeseen external factors. Whether the project is small or large, using project management tools is essential to make costing easier and more accurate.

Time

The third obstacle of the triple constraint is time or planning in project management. This schedule is important project can be carried out according to the wishes of the client, stakeholders, and other parties. You can use Gantt charts, work breakdown structures (WBS), and various time management processes to organize this schedule. However, with Gantt charts, everything updates automatically as team members complete tasks.

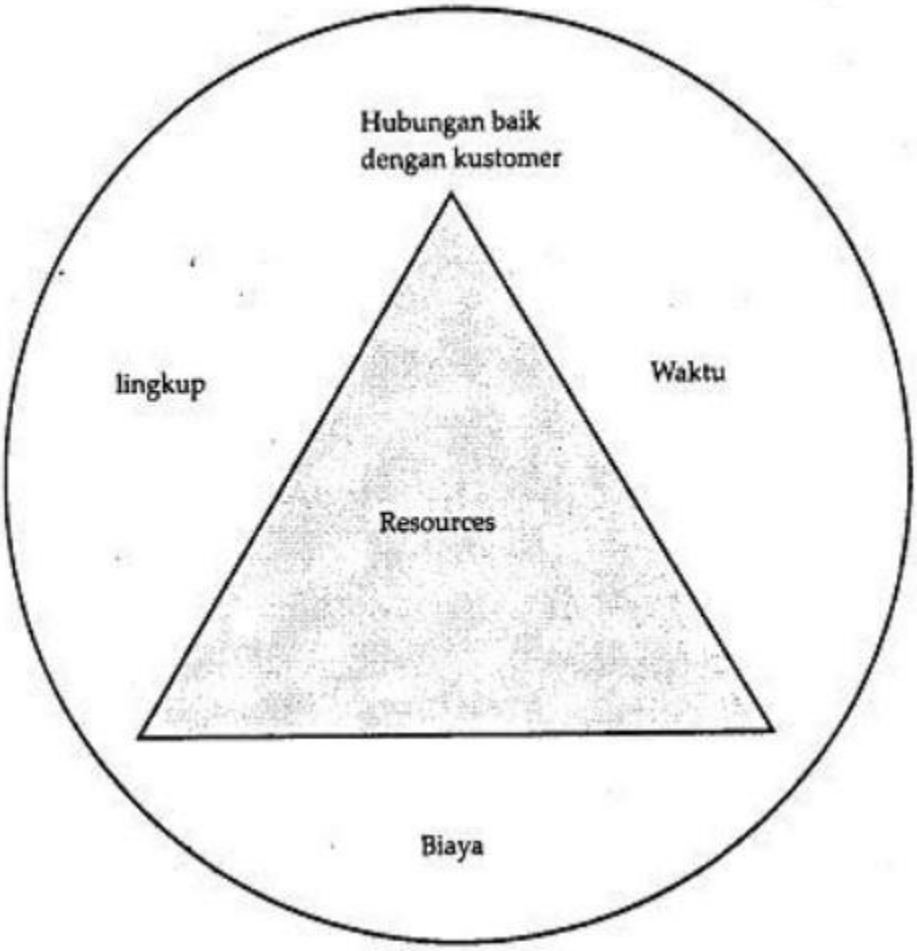
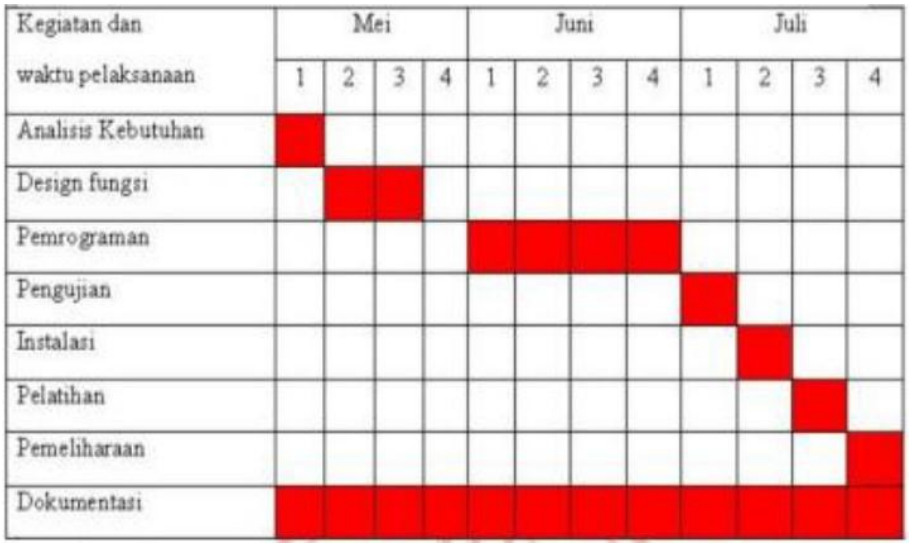


Figure 1. Triangle Project Constraints

Gantt Chart

Gantt charts are used for projects with a small number of team members. Simple, easy to implement, and easy to understand, very useful as a communication tool in project implementation.

According to Budi Kho, a Gantt chart is a type of bar chart that shows project tasks along with their schedule and implementation time, such as when start and the time limit used to complete them.



Kegiatan dan waktu pelaksanaan	Mei				Juni				Juli			
	1	2	3	4	1	2	3	4	1	2	3	4
Analisis Kebutuhan												
Design fungsi												
Pemrograman												
Pengujian												
Instalasi												
Pelatihan												
Pemeliharaan												
Dokumentasi												

Figure 2. Gantt Chart Diagram

Network

The network definition serves the planning, scheduling, and monitoring of construction activities. In network analysis, it requires multiple control systems, including single function, combined function, parallel function, and critical path. Then a network method was found to serve as a planning, timing, and control. Blueprints serve as a guide for the execution of construction projects. Part of the control monitors the flow of project activities and considers quality to ensure specified standards have been defined.

A network is a relationship of Actions described in a working diagram.

1. Project activities are symbolized by arrows in the direction of the symbol. This can be used to identify previous or previous that follow or subsequent. Each is labeled to indicate the type of activity and estimated completion time for each activity.

Figure 3. Arrows

2. Each project activity event is represented by a node. An event or event can be interpreted as the origin or encounter.

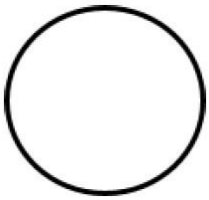


Figure 4. Nodes

3. Arrows with Dotted Lines or Dummy.

Figure 5. Dummy

The purpose of the dummy is to limit the start of activities. Puppet mainly functions as an auxiliary tool for the representation of work assignments. The difference between simulated and normal operations is that operations do not consume time and resources, so the time and costs are zero.

4. Arrows with Bold Lines

These arrows are used to indicate project activities on the critical path:

Figure 6. Arrows with Bold Lines

a. Activity A must be completed before Activity B begins, and Activity B must be completed before Activity C.

Figure 7. Activity A is the predecessor to Activity B, and Activity B is the predecessor to Activity C

b. Activity C can be done before Activity A and Activity B are finished.

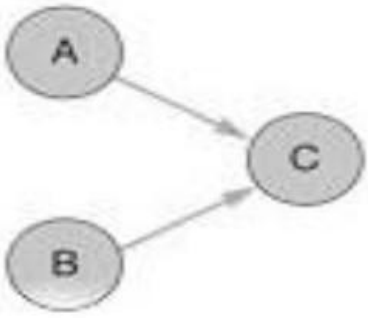


Figure 8. Activity A and Activity B, the predecessors of Activity C

c. Activities B and C can be done after Activity A is finished.

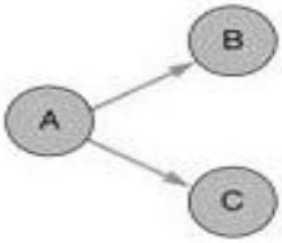


Figure 9. Activity A and Activity B, the predecessors of Activity C

d. Activity C and D can be Activity A and B are completed.

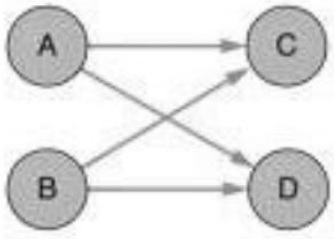


Figure 10. Activity A and Activity B start before Activity C and Activity D

e. Activity C starts after activities A and B are completed. But for activity D it can be done before activity B is finished.

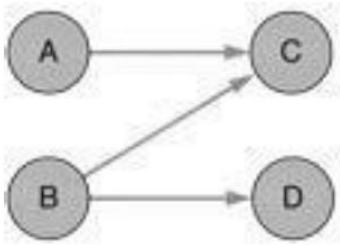


Figure 11. Activity B takes precedence over Activity C and Activity D

f. Activities B and C are done after Activity A is finished, and Activity D is done when Activities B and C

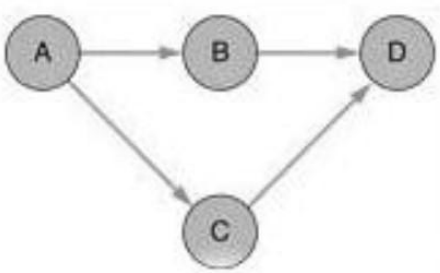


Figure 12. Activity A is a predecessor to Activities B and C, and Activity D becomes

Method Critical Path Method (CPM)

CPM (Critical Path Method) was developed in 1957 by Kelly de Remington-Rand, and Walker de Dupont, an engineer and mathematician. At that time, the method was for planning and controlling processes for complex problems in construction, maintenance, and technology. CPM at that time was used to help build a chemical factory in Dupont (Wijaya, 2013).

The critical path method is a method for determining the critical path of various project activities. According to Levin, CPM is a method of planning and controlling a project by using a work chart as a tool (Levin, 2007). Then according to Heizer and Render, the CPM method is a set of activities in a project that shows the relationship between one activity and another. Using the CPM method, the relationship between project completion time and its resources is considered to be uniquely determined (Heizer and Render, 2006). When calculating projects using the CPM method, you will encounter several terms, including:

1. Activity execution time or duration (D)
2. Earliest Activity Start Time (ES), which states the start of project activity.
3. Earliest Activity Finish Time (EF), which states the initial completion of project activity. If there is one predecessor activity, then the predecessor EF can also be said to be ES in the next activity.
4. Latest Activity Start Time (LS), which states the latest or latest event of a project activity that has started.
5. The latest Activity Finish Time (LF) is the latest occurrence of project activity.
6. Slack Time is free time from a project activity so that it can be postponed without causing delays in project activities.

The CPM method uses the following nodes to describe activities (Khoiroh, 2018):

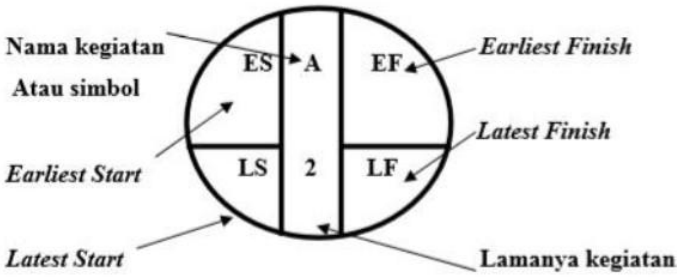


Figure 13. Nodes in CPM

The CPM method uses the critical path as a way to schedule work activities that are interrelated to one another. The critical path, on the other hand, is the organization of various activities in a project

that cannot be postponed and have a reciprocal relationship with each other. The task of the critical path is to find out which activities are affected when activity execution is suspended. When a project has multiple critical paths, more activities need to be tracked.

The longest project duration is used as a reference point for total time estimation.

$$EF = ES + Duration$$

The longest project duration is used as a reference point for total time estimation.

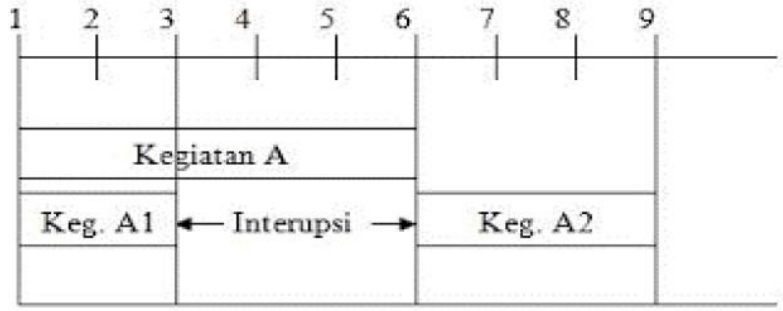


Figure 14. Splitable Activities

An example of network planning using the CPM method can be described as follows:

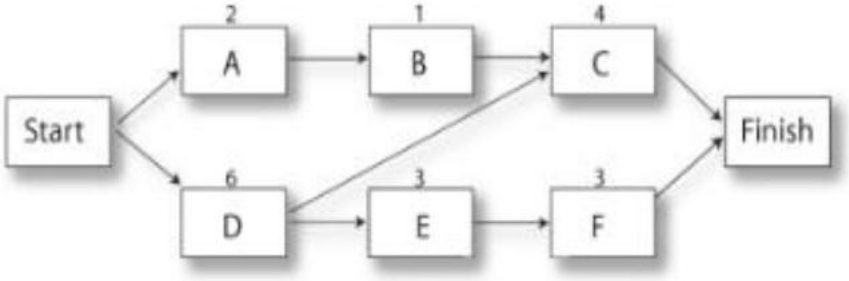


Figure 15. Example of the CPM method Network

Apart from that, we get several advantages when we use the CPM method, such as:

1. Displays a graphic illustration of the flow of activities in project implementation.
2. Provides a prediction of the time required to complete a project.
3. Notify which activities are in an important position so that more attention is given to them and the completion schedule is maintained.

Program Evaluation And Review Technique (PERT) Method

PERT is a network concept development work that first created a network concept for airlines. The need to build this network stems from the need to coordinate and link detailed and interrelated and

interdependent activities. This is done systematically to achieve work efficiency. This procedure is called PERT. PERT is an analytical technique to help plan and manage complex operations that require certain activities to be performed in a certain order, and those activities may depend on other activities. PERT has three-time estimates to complete an activity. This time is determined by how many people are capable of doing the work and how long it will take. The three-time estimates indicate which activities must be completed first before the next activity can start and when activities can start and end. Idle time for an activity is time that can delay the completion of work without delaying work at all. Slack means an activity can be put on hold from the start without putting the project on hold. This full break is also the time allowed to start work without increasing the total working time. Slack means an activity can be put on hold from the start without putting the project on hold. This full break is also the time allowed to start work without increasing the total working time. Slack means an activity can be put on hold from the start without putting the project on hold. This full break is also the time allowed to start work without increasing the total working time.

Conceptual Framework

The framework for thinking in this study is shown in Figure 16. below.

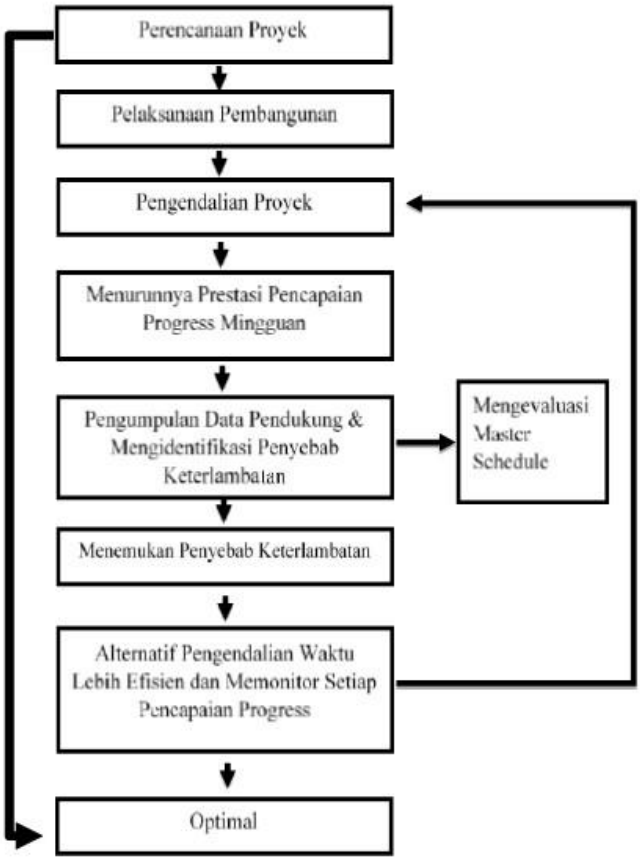


Figure 16. Research Thinking Framework

RESEARCH METHODS

Research Design

The following is a flowchart for evaluating housing construction projects in Pare City, Kediri Regency.

Figure 17. Research Flowchart

Research Limitations

The limitations of the problem in this study are so as not to deviate from the topic of discussion. The trouble in this study has limitations:

1. The data used is data obtained from projects in the City of Pare, Kediri Regency, including:
   a. Data description of housing construction project activities includes data on the sequence of project work activities, the relationship between project activities, and the time of project activity implementation.
   b. The Budget Plan (RAB) for the first house construction project in November 2022 – February 2023.
2. The construction project duration is 8 hours of work per day.
3. This research only examines projects related to the construction of residential houses.

Place and Time of Research

This research is located at the location of Mr. Rudi's residential development project, which is located at Jl. Gatot Subroto, Singgahan, Pelem, Kec. Pare, Kediri Regency, East Java 64213. The research was conducted for 4 months from December 2022 - March 2023 on Thursday - Saturday between 10:00 - 16:00 WIB.

Measurement

The data used in this research is quantitative information. Quantitative data is measurement and verification using statistical methods to measure and support research results. (Sugiyona in Eviatus Syamsiyah, 2014:40). The information needed in this research is the activity schedule, project implementation plan, project budget plan (RAB), and estimates. project work requirements. Primary data comes directly from sources studied at housing project locations in the city of Pare, Kediri Regency. The data to be obtained in primary data include:

1. Work Method
2. Data on the number of workers

Secondary information is information obtained indirectly or through intermediaries. This secondary data can be in the form of media information, notes, pictures, books, reports, and others. The data to be obtained from secondary data include:

1. Draft Budget (RAB)
2. Time Schedule
3. Unit Analysis List
4. And others

Data collection was carried out through field observations and also through secondary data collection from contractors or construction project implementers in the form of budget plan data (RAB),

schedules, and unit analysis lists. The following are the research methods that will be carried out as follows:

1. Data collection
    a. Secondary Data: Draft Budget (RAB); Time Schedule; Unit Analysis List.
    b. Secondary data is data obtained from contractors or executors of construction projects in the form of a Budget Plan (RAB), Time Schedule, and Unit Analysis List.
2. The subject of this research is to analyze the construction project work process using Microsoft Excel.
3. Project scheduling planning uses the Critical Path Method (CPM) method.

Data Analysis Methods

From the information obtained, the researchers managed the data using the CPM (Critical Path Method) method. The Critical Path Method (CPM), also known as the Critical Path Method, is a project operational model that can be described as a network of work items within a project that represents a critical part of project completion. It can be interpreted that the timeliness of a project which is part of critical work can cause project delays because the project completion time is delayed or delayed. CPM is based on a network that is calculated in a certain way, and it can also be software so that a series of important works is created. Activities are represented as points on the network, and events that mark the start or end of activities are represented as arcs or lines between the points.

1. Provides a graphical view of the activity flow of a project.
2. Predict the time needed to complete a project.
3. Shows which activity flow is important to note in maintaining the project completion schedule.

CPM Method Calculation

In identifying the critical path in a network diagram, the CPM method uses several terminologies and calculation formulas, including:

1. How to Calculate Forward (forward computation)

When counting, the count moves from the start event to the end event. The goal is to calculate the fastest time of the event and the fastest start and finish times of the activity. According to Tyutju Tarliah Dimyati and Ahmad Dimyati (2006:182-184), there are three steps involved in the forward calculation, namely:

    a. The fastest time for the initial event to occur is determined on day zero so that for the initial event, TE = 0 applies.

b. If the initial event occurs on day zero then

Figure 18. Initial Event on Day 0

The goal is to calculate the fastest time for an event to occur and the fastest time to start and finish activities (TE, ES, and EF). Formula:

ES(i,j) = TE(j) = 0

EF(i,j) = ES(i,j) + t(i,j)

= TE(i)+ t(i,j)

Where:

ICE =The fastest time the activity starts

TE =The fastest time the event occurs

EF =The fastest time to complete the activity

t = that time required for an activity

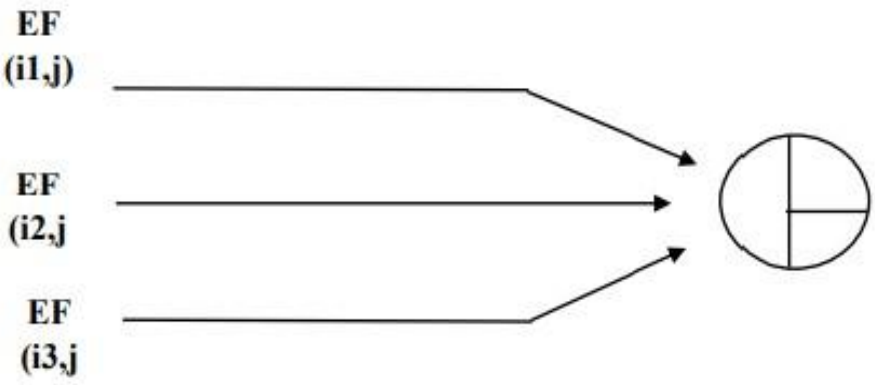


Figure 19. Merge Events

2. Backward Computation Method

In the countdown, the count moves from the end event to the start event. The goal is to calculate the last time of the event and the most recent start and end times of the activity (TL, LS, and LF). Formula:

TL = LS (i,j) = LF-t

LF(i,j) = TLwhere is TL = TE

So:

LS(i,j) = TF(j) - t(i,j)

Where:

LS =The fastest time the event starts

LF =The fastest time the event occurs

TL =The fastest time the event is completed

Q = that time required for an activity

3. Calculation of Allowance Time (backward computation)

The total slack is the amount of time that the last event of that activity finished before the end of the activity if the activity started at the earliest time of that event. Formula:

S = LS - ES - t

Where:

S = Total floats

LS = The latest start of an activity

ICE =The fastest time the activity starts

t = that time required for an activity

Free folate is the time between the earliest end of the activity and the end of that activity if the activity started at the earliest time of the event. Formula:

SF = EF – ES – t

Where:

SF = Free float

EF =The fastest time the activity is completed

ICE =The fastest time the activity starts

t = that time needed for one activity

Calculating Cost and Time Efficiency

The following equation is used to calculate the cost and time efficiency of each work item.

Cost Efficiency

Cost-effectiveness is the optimal percentage of project costs due to acceleration. To calculate the total cost, you can use the equation:

Percentage of cost efficiency = $\left(\frac{T\ Biaya\ normal\ -\ T\ Biaya\ Optimal}{T\ Biaya\ Normal}\right) x\ 100\%$

Time efficiency

Time Efficiency is the percentage of optimal project duration due to acceleration. To calculate the total cost, you can use the equation.

Percentage of project time efficiency = $\left(\frac{Durasi\ Normal - Durasi\ Optimal}{Durasi\ Normal\ Pekerjaan}\right) x\ 100\%$

RESULTS

Research Overview

The subject of this research is a housing project in the Pare de Kediri area. Initially, the construction of this project was due to a change in plans, the landowner wanted to build an apartment, but due to the construction of the Apache cigarette factory which was built right in front of the plots, the housing plan was canceled because in the future the smell of tobacco was afraid of disturbing potential buyers, so the courtyard, cafe, and parking, e.g. This residential object measuring 8 x20 m was built in the Pare area, Kediri district, on a plot measuring 10 x120 m with an area of 1200 m^2.

Description of Research Results

In carrying out this house construction project, the owner must first fill in all the land because the land purchased by the previous owner was a paddy field in the past. Apart from stockpiling the land, the owner should also install a concrete fence around the property to prevent anything unusual and then proceed to the compaction backfill stage as the property is on a road used by heavily loaded vehicles. Once the ground is compacted, the owner wants to pave the area that will be the front-to-back walkway. After the paving work is complete, the construction of a residential house starts from start to finish. The purpose of this study is to find out the mistakes made in connection with the construction project in the country. Therefore, some research results from interviews and field surveys were obtained directly during project implementation. Some of the mistakes made by entrepreneurs and owners themselves, these mistakes include:

1. Delay due to contractor error
    a. Less experienced workers and implementers
    b. Foremen have 2 jobs so they are not always at the project site
    c. Poor work plan

2. Delay due to owner error
   a. Made a big job change
   b. The division of labor for work that is not too important
   c. Delay in the availability of building materials

These mistakes will be used as evaluation material for the analysis of this study and it is hoped that the mistakes above will not be repeated in the course of the next project development.

Data Analysis

This research was analyzed using the CPM method with the following flow:

1. Project Time Implementation Analysis
2. Analysis of Project Implementation Cost Data

Evaluation of project implementation with the following flow:

1. Project Evaluation in Its Implementation
2. Evaluation of Implementation Cost Data
3. Develop Relationships Between Implementation

Identify Cost Efficient and Time Effectiveness

From the calculation, it is known that the total cost of the project after being evaluated is Rp. 160,276,500 with a processing time of 78 days and the daily cost is Rp. 2,226,063. If the implementation of the project uses the CPM method, there is a cost reduction based on the time generated by the CPM method as follows 72 days – 52 days = 20 days; So the project costs obtained are Rp. 2,226,063 x 20 days =Rp. 44,521,260; So Rp. 160,276,500 - Rp. 44,521,260 = Rp. 115,755,240.

Calculating the Percentage of Cost Efficiency

$$\text{Cost efficiency percentage} = \left(\frac{T\ Biaya\ normal\ -\ T\ Biaya\ Optimal}{T\ Biaya\ Normal}\right) x\ 100\%$$

$$\text{Cost efficiency percentage} = \left(\frac{Rp.160.276.500\ -\ 115.755.240}{160.276.500}\right) x\ 100\%$$

$$\text{Cost efficiency percentage} = ((\text{Rp.}44{,}521{,}260\ )/(\text{Rp.}160{,}276{,}500))\text{x}\ 100\%$$

$$\text{Cost efficiency percentage} = 0.278\%$$

Calculating Time Effectiveness Percentage

$$\text{Time Effective Percentage} = \left(\frac{Durasi\ Normal - Durasi\ Optimal}{Durasi\ Normal\ Pekerjaan}\right) x\ 100\%$$

$$\text{Time Effective Percentage} = \left(\frac{72-52}{72}\right) x\ 100\%$$

Time Effective Percentage $= ((20)/72) \times 100\%$

$$\text{Effective Percentage of Time} = 0.278\%$$

Thus the implementation of the project which was accelerated to 52 days affected project costs, this was known from the cost efficiency and time effectiveness obtained by 0.278%. So, the total project cost which was initially Rp. 160,276,500 with an implementation time of 72 days, after the CPM method was carried out it became 52 days with a total project cost of Rp. 115,755,240.

DISCUSSION

From the research that I have done, namely, the one entitled Analysis of Network Planning Using the Critical Path Method (CPM) as a Tool for Evaluation of Project Planning and Control (Case Study on Residential Development Projects in Pare City, Kediri Regency). It was found that there were differences in time and costs before and after using the CPM method which resulted in an effective time and cost efficiency. The result of the analysis is to find the causes that are the delays in the implementation of development projects and evaluate the time and cost then after the evaluation data is obtained so that time and cost are more efficient and effective by taking into account the evaluation data by using the CPM method. The project, which was initially completed in 103 days at Rp. 213,956,500 after being evaluated and if there were no mistakes during project implementation, the normal time was 72 days at Rp. 160,276,500 and then using the CPM method obtained an effective time of 52 days and an efficiency cost of Rp. 115,755,240, and hopefully for the next project the owner and contractor will not make the same mistake as follows:

1. Delay due to contractor error
    a. Less experienced workers and implementers
    b. Foremen have 2 jobs so they are not always at the project site
    c. Poor work plan
2. Delay due to owner error
    a. Made a big job change
    b. The division of labor for work that is not too important
    c. Delay in the availability of building materials

CONCLUSION

Based on the results of the research described above, the authors draw the following conclusions:

1. By using Network Planning for residential housing development projects in Pare, Kediri Regency, you can find out which activities are at risk and cause delays in every activity involved in project development.

2. Using Network Planning in planning the time and activities to be carried out to complete a residential construction project in Pare, Kediri Regency is very useful because with the Network Diagram (CPM) method, it can be seen that the normal time after evaluation is 72 days and after using the CPM method, it is 52 days from the time that has been evaluated from the time of project implementation.
3. Using Network Planning for residential housing projects in Pare, Kediri Regency can increase project time effectiveness and project cost efficiency. This can be seen from the length of time using the network diagram method which only takes 52 days, with a total project cost of Rp. 115,755,240.

SUGGESTION

The suggestions that the author can give for the development project are:

1. Before starting the project, the owner or contractor should prepare a plan using. Network Planning uses the CPM (Critical Path Method) method in preparing planning as a tool to achieve more effective and efficient project time and costs.
2. In connection with the obstacles that have been faced and the delay in project implementation, such as:
    a. Less experienced workers and implementers
    b. Foremen have 2 jobs so they are not always at the project site
    c. Poor work plan
    d. Made a big job change
    e. The division of labor for work that is not too important
    f. Delay in the availability of building materials

The researchers suggest that the owner or contractor must be able to anticipate the obstacles faced, namely by:

1. Looking for workers and implementers who are experienced and also assign project supervision tasks to people who can be trusted.
2. Make a project implementation plan and building budget plan that are certain so that the implementation time can run regularly and without problems.
3. Do not make changes to the project plan in the middle of implementation d. Order building materials with the party following the building budget and request delivery of building materials in stages and on schedule.

4. By implementing Network Planning, the owner or contractor can arrange daily workforce scheduling with minimum fluctuations in labor requirements, so that the scheduling of workforce needs becomes more even.
5. After the owner or contractor draws up a plan using network planning as a tool to achieve more effective and cost-efficient time, it should be adjusted to the availability of funds for project financing so that it can run according to a predetermined plan

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