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Implementation of Critical Path Method in House Development Scheduling Type 300/350 in CV. HILMY Jaya

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The execution of a project requires a management technique from planning through scheduling to the control of the project. The success and failure of the implementation occurs because of the lack of planned project activities and less effective controls such that project activities are inefficient. Companies often experience delays in project completion. The purpose of this study was to determine the effect of scheduling by using the Critical Path Method (CPM) method to streamline the time of construction of the house type 300/350 in CV. Hilmy Jaya. The research method used is description of analysis through the Network Planning method such as the Critical Path Method. The result is that the construction of 300/350 type houses takes 210 days at a cost of IDR 395,680,000 while the construction using the Critical Path Method takes 191 days at a cost of IDR 389,800,000.

Key words: *scheduling, network planning, critical path method.*

Introduction

The development of construction services currently in Indonesia it at its inception. This development requires scheduling as a reference in the implementation of the project and the basis for monitoring the implementation of the project in question. The project is defined as a temporary activity that takes place over a limited period of time with the allocation of certain resources and aims to carry out tasks whose goals have been clearly outlined. Project activities in the process of achieving final results are limited by time and cost. Projects are dynamic, not routine, multi activities with variable intensity, have a short cycle, their activities are clearly defined regarding start and end and there are restrictions on funds to carry out project activities.

CV. Hilmy Jaya is a company engaged in construction. The development system used by CV. Hilmy Jaya is a company that only carries out development while the needs for goods and wages are carried out by the owner. Another system is that the owner fully surrenders the company to the needs of the goods and the wages of the workers associated with the project at a price agreed upon. Companies in determining the time needed in development are guided by planning that has been arranged in the order of activities that have been made based on experience. The company has special standards that are always followed in the process of building a house. However, of the many activities, the company is still conducting random activities that take precedence over the process. The following data on the type of housing construction project 300/350 is presented in Table 1.

Table 1: Duration of House Construction Project Type 300/350

No	Project Name	Address	Duration
1	Puri Arraya	Citangkil, Cilegon	214 days
2	Griya Parung	Cilegon Indah, Cilegon	223 days
3	Serang 1	Kramatwatu, Serang	215 days
4	Serang 2	Ciracas, Serang	225 days
5	Nirwana Curug	Curug, Serang	230 days

The company has set the duration for completion of type 300/350 housing construction activities at 210 days. Based on table 1, it is found that there are differences in the duration of completion of the 300/350 type house project development activities. This difference in duration indicates that the company has not been able to realize scheduling in accordance with company standards. Factors that influence the non-implementation of targets are in accordance with company standards, namely the company's ability to determine activities that need to be completed first and activities that can be delayed in the process. In this case the company must evaluate this.

Scheduling is arranged to be a reference in the implementation of the project as well as a basis for monitoring the implementation of the project in question. Scheduling determines the time and sequence of various stages, the relationship of one activity to another.

Literature Review

Scheduling

Scheduling is the activity of allocating company resources to produce an item or service at a low cost and inventory level. Scheduling is a rostering of an activity: when to start, how long it takes to do each step of the activity and when to finish. Scheduling determines when labor, equipment facilities need to produce products or provide services and is the last stage of

planning before production takes place. The purpose of scheduling is to minimize processing time, subscription waiting time, and inventory levels, as well as efficient use of facilities, labor, and equipment. Scheduling is arranged taking into account various limitations. Good scheduling will have a positive impact, namely low operating costs and delivery times which can ultimately increase customer satisfaction. The scheduling process must go through the following stages:

1. Scheduling future orders without disrupting the constraints of individual work center capacity.
2. Checking the availability of tools and raw materials before giving orders to a department.
3. Make the due date for each job and check progress against the date of need and the travel time of the order.
4. Check the progress against the date of need and the travel time of the order.
5. Provide feedback on factory work efficiency and monitor operator time for analysis of labor distribution, salary, and wages.

Scheduling techniques are divided into two, namely forward scheduling and backward scheduling. Forward scheduling starts the schedule as soon as the requirements are known. Forward scheduling is designed to produce a schedule that can be completed even if it does not mean meeting the due date. In some circumstances, forward scheduling causes a buildup of items in the process. Backward scheduling starts with the due date and schedules the final operation first. The stages in the later work are scheduled at an initial time. This scheduling is used in manufacturing companies and service companies.

Network Planning

Network planning is a model that is used in the implementation of projects / production that provides information about the activities described in a network. In this network, dependence can be seen between one activity and another. Network work planning is one model that is widely used in carrying out projects whose products are in the form of information about activities that are in a diagram of a network that is connected. Work network analysis is a technique related to the problem of determining the order of work that is directed at minimizing the time of completion of a job or project in order to achieve low costs. Some of the benefits of network planning are:

1. Planning a complex project.
2. Scheduling jobs in a way that is practical and efficient.
3. Hold the division of labor from available labor and funds.
4. Rescheduling to overcome obstacles and delays.
5. Determine the trade-off (possible exchange) between time and cost.

6. Determine the probability of completing a particular project.

Network planning is very important because it can provide answers to the following questions:

1. How old is the whole project?
2. Which activities are usually late in completion will result in delays in the entire project?
3. Which activities are not critical, and can be delayed in the process without causing delays in the entire project?
4. How likely is the project to be completed on a certain date?
5. What should be done to shorten the completion of the project at the minimum cost?

Network planning has advantages and disadvantages. The advantages of network planning include:

1. Very useful especially when scheduling and controlling large projects.
2. The concept directly and does not require complicated mathematical calculations.
3. Graphical networks help to see relationships between activities quickly.
4. Analysis of the critical path and slack time helps show activities that need to be considered more closely.
5. Can be applied to various projects.
6. Useful in monitoring schedules and costs.

The disadvantages of network planning are

1. Activities must be clearly defined and the relationship must be free and stable.
2. Prior relations must be explained and netted together.

In network planning there are several techniques used, namely the critical path method and the technique of evaluating / reviewing (program evaluation and review technique). CPM is an activity in a project by sorting a work activity so that it narrows down the overall time of project activities. If an activity in a critical trajectory is postponed, all project activities will be delayed. There are similarities and differences between CPM and PERT:

1. Equations:
   a. CPM and PERT are the techniques most often used in determining project planning, control and supervision.
   b. CPM and PERT describe the activities of a project in a network.
   c. CPM and PERT can be carried out by various analyzes to help managers make decisions related to time, cost or use of resources.

2. Differences:
   a. CPM uses one type of time for estimated time of activity, whereas PERT uses three types of time (most optimistic time, best time, and pessimistic time).
   b. CPM considers the project consists of activities that form one or several trajectories, whereas PERT considers the project to consist of events that follow one after another.
   c. CPM uses an approach that uses arrows as a representation of activities, whereas PERT uses an approach that uses a circle or node as a symbol of activity.

Symbol used in describing a network:

1. Arrow (→), states an activity or activity that requires a certain period of time in the use of a number of resources (labor, equipment, materials, costs). The head of the arrow guides the direction of each activity which shows that an activity starts from the beginning and goes forward to the end with a direction from the left to the top.
2. Node (o), states an event or event as a meeting of one or several activities.
3. Dummy ( ), as symbols of pseudo activity that are useful for limiting the start of activities.

These symbols are used following the following rules:

1. Between the same two activities can only be described with one arrow.
2. The name of an activity is stated in letters or with activity numbers.
3. Activities must flow from low number activities to high numbered activities.
4. The diagram only has an initial event and a terminal event.

In estimating and analyzing the time of each activity in all network diagrams, we will get one or several specific paths from the activities on the network that determine the duration of completion of the entire project. This path is called a critical trajectory. In addition to this critical track there are other trajectories that have shorter periods of time than the critical trajectory. These non-critical trajectories have time to get late called float. Float provides a number of time and elasticity loosens in a network and this is used at the time of network usage in practice or used when determining the amount of material, equipment, and labor. Float is divided into two types, namely total float and free float (Saudi et al., 2019). The following are some notations that are used to facilitate the calculation of time:
TE : Earliest event occurrence time
TL : Latest event occurrence time
ES : Earliest activity start time
EF : Earliest activity finish time
LS : Latest activity start time
LF : Latest activity finish time

t : Activity duration time
TF : Total slack / Total Float
FF : Free slack / Free Float

The timing calculation used three basic assumptions, the basic assumption that the project only has one initial event and one terminal event, the fastest time for an initial event is zero day, when the terminal event occurs at the latest is TL = TE for this event. Calculations are carried out using two means, namely forward computation and backward computation. In advanced calculations, the calculation moves from the initial event to the terminal event, which means calculating the fastest occurrence of events and the quickest start and completion of activities (TE, ES and EF). Advanced calculations are formulated as:

$$TE_j = \max\left(EF_{i1,j}, EF_{i2,j}, \dots, EF_{in,j}\right)$$

In the reverse calculation, the calculation moves from the terminal event to the initial event. The goal is to calculate the moment of the occurrence of events at the latest and when the activities begin at the latest and finish (TL, LS and LF). The countdown is formulated as:

$$TL_i = \min\left(LS_{i,j1},\ LS_{i,j2}, \dots, LS_{i,jn}\right)$$

After these two calculations are complete then we calculate the float. Allowance for completion of projects or production (Sinaga et al., 2019). Two types of time allowances in network planning, namely total float and free float. Total float is the amount of time at which the completion time of an activity can be delayed without affecting the overall project completion schedule. Total float is calculated by looking for the difference between when the activity starts at the earliest and when the activity starts at the earliest or can be calculated by finding the difference between when the activity is completed at the latest and when the activity is completed. Total float is formulated as:

$$TF = LS - ES \quad \text{or} \quad TF = LF - EF$$

where : TF : Total Float
LS : when the activity starts at the latest
ES : the fastest start of activity
LF : when the activity is completed at the latest
EF : when the activity is completed the fastest

Free float is the amount of time at which the completion of an activity can be measured without affecting the moment when the other activities are started or the fastest occurrence of other events in the network. Free float is calculated by finding the difference between the fastest event occurring at the end of the activity with the fastest time the activity is completed. Free float is formulated as: $FF = EF - ES - t$

where : FF : Free Float
EF : the fastest time to complete activities

ES : the fastest start of activity
t : time needed for an activity

An activity that does not have leeway (float) is called critical activity. In other words, the critical activity is formulated as TF = FF = 0.

Research Method

The research method used is the network planning method with the Critical Path Method or critical path. The steps for making network planning are:

1. Inventory activities
2. Arrange relationships between activities
3. Develop a network diagram that connects all activities.
4. Set the time for each activity and arrange it into the network diagram
5. Identify critical paths on the network diagram

Result and Discussion

During the construction of houses so far, CV. Hilmi Jaya has not used special methods in planning the time needed. So far the company in determining the time needed is only basing calculations on experience. Companies have special standards that are always followed. These standards are used so that the project produced is in accordance with the expected quality. The company has followed the standards in the construction of houses but the company still has not used the processing time efficiently. This can be seen from the sequence of work on house construction activities, where of the many activities, the company still carries out random activities that take precedence over the process. The following is the order of the house construction carried out by the company:

Table 2: List of Activities for Building Houses T300 / 350

No	Type of Work	Time (Day)	Cost (Rp.)	Job Code	Prerequisite
1	Preparation	6	5,200,000	A	-
2	Soil (excavation)	6	9,050,000	B	A
3	Column foundation	15	9,700,000	C	B
4	Column / column structure	25	46,100,000	D	C
5	Wall foundation	6	12,600,000	E	C
6	Walls and frames	12	43,700,000	F	E
7	Roof truss	24	40,600,000	G	D
8	Roof (ceiling and tiles)	25	68,500,000	H	G

9	Sanitary ware and installations	20	18,150,000	I	F, H
10	Inside and outside plaster	37	12,120,000	J	F, H
11	Floor	24	11,500,000	K	I
12	Cover (glass, door, window)	20	12,900,000	L	F
13	Painting	40	15,200,000	M	J, K
14	Complementary / accessories	12	18,700,000	N	L
15	Others	6	6,000,000	O	M, N
	Total		330,000,000		

The company also has an indirect cost of building a house of IDR 65,680,000. These costs are costs incurred outside the project work activities and do not depend on the volume of work carried out but depend on the service when carrying out the work. Based on table 2, we can begin to analyze the start and finish time of project activities using forward computation and backward computation.

Table 3: Start Time And Finish Time of Project Activities with Forward Computation

Job Code	Time (Day)	Start (ES)	Finish (EF)
A	6	0	6
B	6	6	12
C	15	12	27
D	25	27	52
E	6	27	33
F	12	33	45
G	24	52	76
H	25	76	101
I	20	101	121
J	37	101	145
K	24	121	145
L	20	45	65
M	40	145	185
N	12	65	185
O	6	185	191

Table 4: Start Time And Finish Time of Project Activities with Backward Computation

Job Code	Time (Day)	Start (ES)	Finish (EF)
A	6	0	6

B	6	6	12
C	15	12	27
D	25	27	52
E	6	27	89
F	12	89	101
G	24	52	76
H	25	76	101
I	20	101	121
J	37	101	145
K	24	121	145
L	20	101	173
M	40	145	185
N	12	173	185
O	6	185	191

Table 5: Calculation of Total Float (TF) and Free Float (FF)

Job Code	Time (Day)	ES	EF	LS	LF	TF	FF
A	6	0	6	0	6	**0**	**0**
B	6	6	12	6	12	**0**	**0**
C	15	12	27	12	27	**0**	**0**
D	25	27	52	27	52	**0**	**0**
E	6	27	33	27	89	56	0
F	12	33	45	89	101	56	0
G	24	52	76	52	76	**0**	**0**
H	25	76	101	76	101	**0**	**0**
I	20	101	121	101	121	**0**	**0**
J	37	101	145	101	145	7	7
K	24	121	145	121	145	**0**	**0**
L	20	45	65	101	173	108	0
M	40	145	185	145	185	**0**	**0**
N	12	65	185	173	185	108	108
O	6	185	191	185	191	**0**	**0**

Based on table 5, we can determine the critical path. The critical path is a path that has a total float and free float is zero. This track has the longest amount of time compared to all other possible tracks. The amount of time on the critical path equals the age of the project. Another way that can be used to determine the critical path by calculating the length of each existing track.

CV. Hilmi Jaya has three trajectories including: A-B-C-D-G-H-I-K-M with a project time of 191 days, A-B-C-D-G-H-J-M with a project time of 179 days, and A-B-C-E-F-L with 83 days. Of the three tracks, the critical path which is the longest path is the path A-B-C-D-G-H-I-K-M. Based on this critical trajectory, the sequence of activities for construction of houses is preparation, soil (excavation), column foundation, column / column structure, roof truss, roof (ceiling and tiles), sanitary ware and installation, floor and floor, painting, and work others. All of these activities cannot be delayed in the process because they will cause delays in the overall completion of the project. The period of completion of the T300 / 350 housing construction project on the CV. Hilmi Jaya as a whole by using Critical Path Method is 191 days.

Table 6: Comparison of Costs for Settling Construction of Houses T300 / 350

	Old Method	Critical Path Method
Direct Costs	Rp. 330,000,000	Rp. 330,000,000
Indirect Costs	Rp. 65,680,000	Rp. 59,737,523
Total	Rp. 395,680,000	Rp. 389,737,523

The time period and cost of completing the construction of a T300 / 350 house using the Critical Path Method is 191 days with a rounding off of Rp. 389,800,000 so that time efficiency of 9.04% can be calculated and cost efficiency of 14.86%.

Conclusion

The company scheduling the construction of houses T300 / 350 does not use special methods and is guided by planning arranged in the order of activities. The company has special standards that are always followed in the process of building a house but still carry out random activities which are prioritized. The company targets the completion of construction of the T300 / 350 210 day house at a cost of Rp. 395,680,000 (Rau, 2017). The use of Critical Path Method results in activities that are critical activities that cannot be delayed in the process because they affect the delay in the overall completion of the project. These critical activities include preparatory work, soil (excavation), column foundation, column / column structure, roof truss, roofs (ceilings and tiles), sanitary ware and installations, floors and fixtures, painting and other works. The time to complete the construction of the T300/350 house using the Critical Path Method is 191 days at a cost of Rp. 389,800,000. The application of the Critical Path method in completing the construction of the T300 / 350 house can make it 19 days or 9.04% efficient and save costs of Rp. 5,880,000 or 14.86%.

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