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Application of Scheduling Method: Case Study Semarang-Solo Highway Project Phase II Segment Bawen – Solo, Section Three Bawen – Salatiga, Indonesia

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Abstract:

The development of transportation in Indonesia is currently growing rapidly. Road is an infrastructure that is very supportive for the community needs. Highway construction is used as a mainstay of land transportation routes in Indonesian large cities. By the existence of freeway network system, it is expected that all land transportation activities can run well. Scheduling data in this project is used to apply the scheduling method Bar Chart, Critical Path Method (CPM), and Line of Balance (LoB) to be analyzed, so that the appropriate scheduling method which best fits the characteristics of the project can be determined. Based on the research results a conclusion is obtained, the schedule planning of Semarang-Solo highway project phase II: Bawen-Solo section 3: Bawen-Salatiga can be applied in Line of Balance (LoB) method which already fits with the characteristic of the project by having linear / repetitive activity items, but it does not rule out the possibility to combine with other methods to complement the needs of scheduling advantages and disadvantages in the project both before or in progress.

Keywords: Case study, highway project, scheduling method

1. Introduction

Project is a temporary activity that takes place in a limited period of time, with the allocation of certain resources, and is intended to carry out tasks whose goals have been clearly outlined (Suharto, 1995). Scheduling construction projects is a tool to determine the time needed by an activity in completing activities. Schedule planning on construction projects, in general, consists of scheduling time, labor, equipment, material, and finance. The accuracy of scheduling in project implementation greatly influences the avoidance of many losses, such as swelling construction costs, late project submission, and disputes or claims (Irika & Lenggogeni, 2013: 7). Transportation sector in Indonesia is currently growing rapidly. Road is an infrastructure that is very supportive for the community life, Road damage can have an impact on social and economic conditions in land transportation facilities. Highway construction is used as a mainstay of land transportation routes in Indonesian large cities. By the existence of freeway network system, it is expected that all land transportation activities can run well.

Highway development projects that fits with the characteristics of the project require the right scheduling planning method, so that the costs, time and quality goals are as expected.

In general, in the scheduling of contractors (Project Implementers), developers (developers) or project owners usually use one of several common methods that is commonly used in scheduling project implementation times, including Chart Bars, Network Diagrams (CPM, PDM, PERT), and Linear Scheduling Method (Line of Balance, and Time Chainage Diagram). However, considering that the method functions as a tool, its use depends on the accuracy of the selection method used in accordance with the type and characteristics of the planned construction project.

1.1. Formulation of the Problem

- How is the application of several scheduling methods in highway projects?
- How to apply scheduling methods that are in accordance with the characteristics of the highway project?

1.2. Purpose and Objectives

- Analyze the application of several scheduling methods in highway project activities.
- Applying the most appropriate scheduling method between Bar Chart, Critical Path Method (CPM), and Line of Balance (LoB) with the characteristics of the activities contained in the project.

2. Literature Review

Project is a temporary activity that takes place in a limited period of time, with the allocation of certain resources and is intended to carry out tasks whose objectives have been clearly defined the main features of the project are as follows (Suharto, 1997):

- Aim to produce a certain scope in the form of the final product or final work result.
- In the process determined the amount of costs, schedules, and quality criteria.
- Being temporary, the age is limited by the completion of the task. The starting and ending points are clearly defined.
- Non routine, not repetitive. The type and intensity of activities changes throughout the project.

Scheduling methods that have often been used in project construction include CPM (Critical Path Method), PERT (Project Evaluation and Review Technique), PDM (Precedence Diagram Method), all of which are the results of the development of network and beam charts. (Gantt Chart). In addition to the scheduling method above, also known as the Line of Balance scheduling method, which was historically developed before the CPM method. The method of scheduling the balance line (LoB) is less well known by the implementers of construction projects, because it is generally used in manufacturing industries, but can also be applied as a scheduling technique for linear projects such as: construction of the same type of housing, piping installation work, road construction work highway, as well as in multi-storey building projects that have identical structure plans for each floor (Oakland, 1994). According to (Paulus, et al., Construction project management pg 26), scheduling methods include:

- Beam Diagram (Gantt Bar Chart)
- Time / production graph
- Arrow diagram (Critical Path Method)
- Precedence diagram
- Time scale diagram

Critical Path Method (CPM) is a method designed to optimize project costs where it can be determined when the exchange of costs and time must be done to meet the project completion schedule with minimum costs (Handoko, 1993: 401). Some things that need to be known in scheduling projects are using the Critical Path Method (CPM) method, which is the Critical Path Method (CPM) elements which include:

a. Arrow (arrow), activity (activity), job

- The arrow shows the relationship between activities, and also includes the duration.
- An arrow represents one activity.
- The beginning of the arrow is expressed as the beginning of the activity and the arrowhead as the end of the activity.

There are three types of arrows:

- Ordinary arrows indicate an activity that can be done normally
- Dashed arrows shows activities Dummy.
- Thick arrows indicate an activity that must be considered (critical).

2.2. Small Circle (Node), Activity / Occurance, Event

Figure 1

Where :

- ES: Early Start is the earliest moment of an activity
- EF: Early Finish, which is when the activity ends the earliest
- LS: Latest Start, which is when you start the latest allowable for an activity
- LF: Latest Finish which is when the latest is allowed for an activity.

PERT (Project Evaluation and Review Technique) is an analytical method designed to assist in the scheduling and control of complex projects, which requires that the main problem discussed is a technical problem to determine the activity schedule along with its cost budget so that it can be completed in a timely and costly manner (Handoko, 1993: 401).

The PERT method (Project Evaluation and Review Technique) is marked as a stochastic method. The purpose of this method is to identify the critical path in the graph. This graph represents the model of the project. The PERT algorithm implementation is based on the critical path method (CPM) (Doubravský & Dorskocil, 2013).

PDM (Precedence Diagram Method) basically focuses on the problem of the balance between the cost and time of completion of the project. PDM (Precedence Diagram Method) emphasizes the relationship between the use of a number of workers to shorten the time of implementing a project and increase costs as a result of the addition of the workforce. PDM (Precedence Diagram Method) also considers the relationship of dependence between activities and duration of each activity. In the manufacturing industry there is a scheduling method that when doing location and leveling the workforce

takes into account the weighting of the position first, then calculates float time. This scheduling method is called Ranked Positional Weight Method (RPWM).

Figure 2: Symbol of PDM Activity
(Source: Ervianto, 2005: 249)

Bar Chart was found by Gantt and Fredrick W. Taylor in 1917, in the form of a beam chart, with the length of the beam as a representation of the duration of each activity. The format of the beam chart is informative, easy to read and effective for communication and can be made easily and simply. The beam chart consists of the y axis that states the activity or work package from the project scope, while the x axis states the unit of time in days, weeks, or months as its duration. In this chart milestones can also be determined as part of the target that must be considered in order to smooth overall project productivity. For the process of updating the beam chart can be shortened or extended which indicates that the duration of the activity will increase or decrease as needed in the process of repairing the schedule (Husen, 2009).

LoB (Line of Balance) is a project scheduling method intended for project planning that has repetitive activities. As for housing projects, highway construction, pipe installation and so on. Especially projects with relatively few activities with repetitive activities. LoB (Line of Balance) also functions as a media control and monitoring, because it can be used to show the number of jobs that have been completed within a certain period of time, so that the level of production can always be controlled according to the initial plan. This is indicated by the lead times. Lead times are times that a job must pass until all activities are completed. The LoB (Line of Balance) concept is based on the knowledge of how many units must be completed in a few days so that the unit delivery program can be achieved, because the delivery speed is assumed constant, the relationship between the LoB (Line of Balance) quantity q and time t is linear (Lumsden, 1968). This is shown in Figure 3 as a slash/tilted line.

Figure 3: Relationship between Lob
Quantity Q and Time T
Source: Arditi Et Al., 2002(2)

It can be seen from Figure 3 above the relationship between LoB quantity q and time t is linear with the following formula:

$$q = mt + c$$

Where :

q is the unit quantity in LoB m is the speed of delivery

t is time c is a constant

Because the value of c coincides with the q axis,

Then obtained the formula:

$$q_2 = m(t_2 - t_1) + q_1, \text{ or } t_2 = [(q_2 - q_1) / m] + t_1$$

Where :

q_1 is the 1st unit quantity in LoB; t_1 is the time for unit 1

q_2 is the second unit quantity in LoB; t_2 is the time for unit 2

LoB (Line of Balance) is defined on the basis of the following (Mawdesley, 1997):

- Based on the level of delivery or handover rate
- The logic of the basic construction of a repeating unit is described in the form of a Network called the "Production Diagram".
- Constants from the production level usually use units of units / unit time.

The activity line on the LoB (Line of Balance) method must not intersect (no cross) or in other words the series of activities must not interfere with each other or overtake each other. This means that progress or progress of the activities of the activities that follow (successors) may not precede predecessor activities. If this happens, there will be a

conflict of activities or can interfere with all the course of the project (Hinze, 2008: 302). So, it is necessary to delay the type of work so that the planned work continues to run according to the activities that follow (successors) and predecessor activities.

Figure 4: Lob Scheduling That Shows the Existence of Conflicts That Must Be Avoided
(Source: Hinze, 2008: 302)

The initial start and finish in the first and last units must be calculated for each activity on all possible paths between the origin and end of the node on the unit network. To do this, LOB analysis (Line of Balance) must be done in the following way:

- After the first activity in the first unit starts at zero, the production level of the next activity must be compared with the first activity. If the production level of the first activity is faster than the next activity, the next activity can begin right after the first activity in the first unit is completed.
- If not, the next activity cannot start according to the time available, to prevent conflict in the logical relationship between the two activities. Therefore, the start time of the next activity of the first unit can be derived from the time of the beginning of the next activity of the last unit, which can be started right after the first activity in the last unit is completed

3. Analysis and Discussion

The planning and scheduling method in the Semarang-Solo Highway Project Phase II : Bawen-Solo Section 3: Bawen-Salatiga was applied to the scheduling of the activities of the Bar Chart method, Line of Balance (LoB) and Critical Path Method (CPM) so that the scheduling method was most according to the characteristics of the project. The data obtained is in the form of the Bar Chart method, which has been simplified in the form of MS. Project. For black is a heading of a collection of activity items below it, while blue is a sub heading of activity items on it. The project schedule for Semarang-Solo Highway Project Phase II : Bawen-Solo Section 3: Bawen-Salatiga can be seen in Figure 5below.

Figure 5: Bar Chart of Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga

3.1. Discussion Results of the Bar Chart Method

In the Bar Chart a set of activity items is arranged in a vertical direction column, while the horizontal direction column shows the time scale. The length of the bar chart shows the duration of the activity. This Bar Chart method is still widely used in construction projects because it looks simple, easy to make and understood by the user, both from the boss level to the workers in the field. But this Bar Chart method has limitations, where Bar Charts cannot specifically show a logical relationship of dependence between activities, so it is difficult to know the impact due to delay by an activity against the overall schedule.

Figure 6: Analysis Bar Chart of Semarang-Solo Highway Project Phase II : Bawen-Solo Section 3: Bawen-Salatiga

3.2. Discussion Results of the Critical Path Method (CPM)

From the diagram below, it can be seen that the dependency relationship between one activity and another activity is specific, by using the FS (Finish to Start) relationship and easy to update, and can estimate the overall project completion time because it has a mathematical calculation. In addition, the Critical Path Method (CPM) can also show the critical trajectory of project activities so that in the event of a project delay, the job priority to be corrected is easy to be done. By The calculation of forward and backward, critical trajectory of the Critical Path Method (CPM) diagram on the Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga can be seen in Figure 7below:

Figure 7: Analysis CPM on Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga

Figure 7shows the overall activity of scheduling with the Bar Chart method that is applied in the Critical Path Method (CPM) method. From the picture, there is a dependency relationship between one activity and another. Critical Path Method (CPM) shows the critical trajectory of project activities so that if there is a project delay, the priority of the work to be corrected becomes easier. With the calculation of back and forth, the critical path of the Critical Path Method (CPM) method is the sequence of activities that go through the A-B-C-D-G-E-H activity path which is marked with a red dotted arrow, with a resolution time of 425 days. The activity items in the critical trajectory should not be late so that the overall project completion time is not delayed.

3.3. Discussion Results of Line of Balance (LoB) Method

As stated in the previous chapter, Line Of Balance (LoB) is a project scheduling method intended for project planning that has repetitive activities. The line of activity in the Line Of Balance (LoB) method may not intersect (no cross) or may not interfere with each other or precede each other, meaning the progress or progress of the work from the following activities (successors) may not precede the activity that preceded it. If such a thing happens, then there will be a conflict of activities or can interfere with all the course of the project.

Code	Activities	Duration (days)	Activities That Are Followed
A	Land Cleaning	7	-
B	Construction Work	7	A
C	Job and Detour Work	14	B
D	Land Works	248	B
E	Drainage work	61	D,G
F	Structural Work	247	C
G	Pavement Work	71	F
H	Other Jobs	18	E

*Table 1: Lob Schedule Semarang-Solo Highway Project
Phase II: Bawen-Solo Section 3: Bawen-Salatiga*

Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga has a length of 866 meters. In this case study, the Line Of Balance (LoB) method will be applied to the scheduling highway project. Job activities in this scheduling consist of:

- Land Cleaning
- Construction Work
- Job and Detour Work
- Land Works
- Drainage work
- Structural Work
- Pavement Work
- Other Jobs.

From calculations using the Line Of Balance (LoB) method, the following calculations are obtained:

min cycle time : 248 days

max cycle time : 673 days

assuming : 0,5 m/

Number of products: 0, 5 m

Operation time per days : 140 days

Cycle Time = $\frac{\text{Number of products}}{\text{Operation time per days}}$

Operation time per days = 280 days

Number of workstation = $N = \frac{\text{max cycle time}}{\text{Cycle time}}$

= 2.4 $\approx$ 3,0

Table 1 being applied in Line Of Balance (LoB), as stated in Figure 4.5 below:

*Figure 8: Lob Schedule Semarang-Solo Highway Project
Phase II: Bawen-Solo Section 3: Bawen-Salatiga*

3.4. Analysis of Scheduling Methods Application

From the results of each schedule planning method of Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga the writer can produce analysis application methods that match the characteristics of the project, as follows:

Figure 9: Application Analysis Project Planning and Scheduling Methods

Bar Chart is simple and easy to understand, but does not specifically show the logic of dependency between activities and cannot directly detect activities that experience disruption in scheduling projects.

Critical Path Method (CPM) has reliability in showing specifically the relationship of logic dependence between activities, and can determine the critical path of project activities so it can be known if there is a delay so that it is suitable for complex projects.

Line of Balance (LoB) can directly detect activities that experience interference in the project by seeing whether there are intersecting bar charts, so that it is suitable for projects that have repetitive/linear activities because they can directly detect disturbed activities in project scheduling such as the highway project.

From Figure 9 above can be known that for scheduling planning method of Semarang-Solo Highway Project Phase II: Bawen-Solo Section 3: Bawen-Salatiga with project characteristics that have linear activities can be applied in the Line Of Balance (LoB) method but it is possible for the Bar Chart and Critical Path Method (CPM) methods to complement schedule planning needs both before or when the project is in progress.

3. Conclusion

The results of the study of literature study and discussion of application analysis of scheduling Bar Chart, Line of Balance (LoB) and Critical Path Method (CPM) methods, concluded as follows:

Various project planning and scheduling methods have different characteristics in project applications, including:

- Bar Charts are simple and easy to understand, but do not show specifically the relationship of logical dependence between activities and cannot directly detect activities experiencing disruption in scheduling projects.
- Critical Path Method (CPM) has reliability in showing specifically the relationship of logic dependence between activities, and can determine the critical path of project activities so that it can be known if there is a delay so that it is suitable for projects that are complex
- Line of Balance (LoB) can directly detect activities that experience interference in the project by seeing whether there are intersecting bar charts, so that it is suitable for projects that have repetitive / linear activities because they can directly detect activities experiencing disruption in project scheduling on certain time as in the Toll Road project

The Line of Balance (LoB) has repetitive activity items, so that it can be applied with the Phase II Semarang-Solo Toll Road Project: Bawen-Solo Section 3: Bawen-Salatiga which is in accordance with the characteristics of the project, by having linear activity items, do not rule out the possibility of combining with other methods to complement the needs of scheduling advantages and disadvantages in the project both before and in progress.

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