Construction Project Evaluation Using CPM-Crashing, CPM-PERT and CCPM for Minimize Project Delays

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Abstract. This research conducted in one construction company in Indonesia, the company was facing several problems, many projects that already ended have delays. Overdue payment one of the projects can reach Rp 252,544,148.-. For calculating late payment that the company can save researcher using Critical Path Method (CPM)-Crashing. CPM-Crashing method can accelerate project duration by increase resource budget, so company doesn’t need to pay overdue payment. The result of CPM-Crashing is company can save Rp. 227,584,147.- late payment. To anticipate project delay proper planning is required. One of project planning method is project scheduling. Great loss because of the overdue amount, the company must evaluate their project schedule. The Researcher using CPM-Project Evaluation Review Technic (PERT) and Critical Chain Project Management (CCPM) both methods can give new project schedule. CPM-PERT can give probability project finish and CCPM can give new project schedule. The result of this research is probability project is not delay is very low that is only 55% project can finish on time, the company must try CCPM schedule.

Keywords: Project, Overdue Payment, Critical Path Method, Critical Chain Project Management, Delay

1. Introduction

Every project has a deadline so that completion is not late, but every project does not always go according to schedule. Many factors make the project not run according to schedule [1]. The late fee received by a construction company in Jakarta was up to Rp. 252,544,148 with the number of days of delay for 21 days. The number of losses suffered by the company so that it needs to be evaluated on how much money could be saved if the project was not late. Delays in the project can be anticipated by accelerating the project (crashing) but still paying attention to the cost factor. Project acceleration is carried out by increasing the number of overtime, workers, and working tools [2]. CPM-Crashing can accelerate the duration of the project by increasing human resources so that the project is not late and does not have to pay late fees [3].

Project scheduling and control are the main tasks in construction project management. In addition, an effective project scheduling method is very important to ensure the success of project performance [4]. This study aims to compare a suitable and effective method for scheduling construction projects in a construction company in Jakarta. The Critical Path Method (CPM) is a project scheduling and evaluation method with a deterministic approach and a Project Evaluation Review Technic (PERT) method using a probabilistic approach [5]. CPM-PERT method can be used to analyze project duration, although it has a slight difference but is used simultaneously because of the same function [6]. CPM is a fundamental quantitative technique developed for project management assuming a
deterministic turnaround time. CPM also determines the minimum time required to complete the project [6] [7]. CPM was developed in 1957 by J.E. Kelly of Remington Rand and M.R. Walker of DuPont to help build a chemical plant at Dupont [8]. In CPM, there is the term slack time, or the time to delay an activity without changing the overall project period. Slack time (S) is obtained using the following formula:

\[ S_{ij} = LS_{ij} - ES_{ij} \]
\[ S_{ij} = LF_{ij} - EF_{ij} \]  

(1)

PERT is an engineering tool with a probabilistic approach that is used in situations with a high degree of uncertainty in the aspect of the activity period [9]. PERT originated in the US Navy in 1958 as a tool for scheduling weapons systems development [9]. The PERT calculation technique has three estimated numbers, namely optimistic time (a), most likely time (m) and pessimistic time (b). To get the expected activity duration (te), the standard deviation of activity (s) and variance (v) is used the formula [9]:

\[ te = \frac{a + 4m + b}{6} \]  
\[ s = \frac{b - a}{6} \]  
\[ v = s^2 \]  

(2) (3) (4)

The probability of achieving the target is expressed by (z), namely the relationship between the expected time (EET) and the target set T (d) [9]:

\[ z = \frac{td - EET}{\sqrt{2v}} \]  

(5)

A new method for dealing with uncertainty in projects has developed, namely the Critical Chain Project Management (CCPM) method. This method was first introduced by Goldratt in 1997. CCPM is the application of Theory of Constraints which is a project planning method that focuses on the resources used to perform tasks in the project [10]. CCPM is also recommended by the Project Management Body of Knowledge (PMBOK), as a new breakthrough in a revolutionary way of thinking to complete a project, improve scheduling capabilities, and reduce predetermined costs [11]. CCPM is a method that must eliminate multitasking, student syndrome, parkison's law, as late as possible, backward planning, no early finishes and eliminate hidden safety and remove it in the form of a buffer (buffer) behind the project and focus on the final completion of the project [11].

Buffer consists of project buffer and buffer feeding. The project buffer is the spare time that is placed at the end of the critical chain of a project. Meanwhile, buffer feeding is a buffer time that is useful as a link between non-critical chain activities and critical chain activities. Feeding buffers also function as time reserves when there are delays in non-critical chain activities. Buffer time will ensure the critical chain and integrity of the project schedule as a whole [5][10]. The formula for calculating the size of the buffer is to use the SSQ (Square Root of the Sum Square) calculation by determining the upper and lower limits of each activity to find the difference in the duration. The difference in duration is denoted by the letter (D) [6], [12].

\[ B = \sqrt{\sum_{i}^{n}(D_{0_i} - D_{1_i})^2} \]  

(6)

\[ B = Buffer \]  
\[ D_{0_i} = Duration \text{ that has spare time} \]  
\[ D_{1_i} = Duration \text{ that has not spare time} \]
There are rules for the size of the buffer project. The size of the buffer project should not be less than 25% of the critical chain duration if the buffer project duration is less than 25% then the input buffer project is 25% of the critical chain duration [13][14]. The purpose of this research is to determine the current scheduling using the CPM method, determine the savings obtained from the project using crashing, determine the project scheduling planning model using each method and determine the duration and cost of project scheduling planning that can be obtained from the project using each of the methods.

2. Research Methodology

The research begins by looking for scientific methods of project management as problem solvers and searching for supporting journals as a reference for spelling research. The next stage is to identify and solve problems with the methods studied in the preliminary studies. The problem is the delay in the project so that the company gets a large fine. At the data collection stage, there are two types of data, namely primary data and secondary data. Primary data is obtained by means of observation and interviews, secondary data is obtained by taking company data. Secondary data taken are project scheduling planning, existing project scheduling and project financial reports.

The first method used is CPM and crashing. This method is useful for providing evaluation and input costs that can be saved if the project is not late. The data used are the results of interviews with project managers and existing project scheduling. The second method used is CPM-PERT. This method is useful for providing scheduling suggestions to the company and also the probability of the project being completed on time. The data used are the results of interviews with project managers and project scheduling planning. The third method used is CCPM. This method is useful for providing scheduling suggestions to companies. The data used are the results of interviews with project managers and project scheduling planning. The next step is to calculate the project cost based on labor, then make a comparison from CPM-PERT, CCPM-SSQ. The comparisons made include project duration and project costs. The final stage is to make conclusions that are tailored to the results obtained from the research.

3. Result and Discussion

This study uses the CPM-Crashing, CPM-PERT and CCPM methods. CPM-Crashing is used to calculate how much money can be saved if the project is not late, while the applications from CPM-PERT and CCPM are used to provide scheduling suggestions. Based on the primary data obtained from the company, it is known that there are 34 types of work to complete the project, where all work is categorized into 13 categories of work, namely foundation work, structure, wall work, wall cladding, roof work, ceiling work, floor work, frame work doors and windows, installation of hinges and locks, painting, installation of water installations, installation of sanitary accessories and electrical work. Evaluation of project scheduling is done by looking for critical chains and then from that scheduling, crashing is carried out to find costs incurred to eliminate late costs. Scheduling evaluation is obtained from real data and then calculated by the CPM-Crashing method. The acceleration time is 75% of the working day and the acceleration fee is 125% of the activity cost. The data in Table 1 shows the computation of the CPM-Crashing critical path.

| Symbol | Predecessor | EF | L | LF | Slack | Critical Path (Yes/No) |
|--------|-------------|----|---|----|-------|------------------------|
| 1      | -           | 12 | 12| 12 | 0     | Yes                    |
| 2      | 1           | 24 | 12| 24 | 0     | Yes                    |
| 3      | 2           | 42 | 18| 42 | 0     | Yes                    |
| 4      | 1           | 24 | 12| 24 | 0     | Yes                    |
| 5      | 2,4         | 42 | 18| 42 | 0     | Yes                    |
| 6      | 3,5         | 96 | 54| 96 | 0     | Yes                    |
| 7      | 4           | 42 | 18| 42 | 0     | Yes                    |
| 8      | 5,7         | 84 | 42| 84 | 0     | Yes                    |
Based on Table 2, the critical critical project 1 can be identified paths, namely 1-4-7-8-15-18-19-28-29-30. The project was carried out within 270 days and experienced delays for 18 working days.

Table 2. Project Acceleration Costs

| Sequence of Activities | Crashing Cost/Day (IDR) | Maximum Acceleration | Crashing Cost (IDR) |
|------------------------|------------------------|----------------------|---------------------|
| 30                     | 600.000                | 3                    | 1.800.000           |
| 20,24                  | 1.520.000              | 12                   | 18.240.000          |
| 26,29                  | 1.640.000              | 15                   | 4.920.000           |
| 1                      | 1.680.000              | 3                    |                     |
| 25,28                  | 1.757.144              | 7                    |                     |
| 10,15                  | 3.757.500              | 3                    |                     |
| 17,19                  | 4.230.000              | 1                    |                     |
| 6,8                    | 4.563.000              | 10                   |                     |
| 2,4                    | 4.800.000              | 3                    |                     |
| 10,16,18               | 5.647.500              | 1                    |                     |
| 3,5,7                  | 6.817.500              | 4                    |                     |
| 6,9,15                 | 6.840.000              | 3                    |                     |
| **Total**              |                       | **18**               | **24.960.000**      |

Table 2 shows that the crashing cost to get rid of the fine is IDR 24.960.000. If the project crashes, it can save money as much as IDR 227.584.147. Evaluation of project scheduling planning aims to find the probability that the project can be completed using the CPM-PERT method. The data used is project scheduling data at the planning stage. The result of this calculation is the probability of the
Based on Table 3 project planning X (PERT), the critical chain of project x planning is 1-4-7-8-15-18-19-25-31-32. The project plan has a period of 252 days with a project cost of IDR 1.054.540.000. Based on the PERT calculation, the critical chain variance value obtained is 57 and the expected time of the critical path is 252 days. The Z value is 0.13. By using the Z table, the probability that a project can be completed in 252 days is 0.5517 (55%). If the project wants to get a 99% probability of completion, the project completion will fall on day 281 with a project deadline of 252 days. Based on CCPM calculations, the critical chain is 1-4-7-8-15-18-19-25-30-31-32. The project duration is 189 days. It is known that the project buffer is below 25% of the total critical chain duration, so the project buffer entered is 25% of the critical chain, which is 48 days. Based on the
calculation, the total project duration is 240 days. 189 is obtained from the project duration, 48 days is obtained from the project buffer, and 3 days is obtained if feeding buffer 1 occurs simultaneously with the critical chain. The project cost is IDR 789,800,000 and if the entire buffer time is used, the cost will be IDR 886,782,044.

4. Conclusion
The critical path of Project X’s CPM-Crashing method is Foundation 1 - Structure 1 - Wall 1 - Wall 2 - Roof 1 - Ceiling 1 - Ceiling 2 - Frames, Doors, Windows 1 - Painting 1 - Painting 2 - Painting 3. The project is being carried out within 270 days and experience a delay of 21 or 18 working days. The savings obtained if the project is not late is IDR 227,584,147. With the CPM-PERT analysis project X was completed in 252 days with a project cost of IDR 1,054,540,000 and the project probability was completed on time was 55%. Based on the CCPM analysis, the project will be completed in 189 days and if the buffer is used up to 215 days, the project cost incurred is IDR 789,800,000 and if the buffer is used it will be IDR 886,782,044.-. From these comparisons it can be seen that scheduling using CCPM is better than scheduling using CPM-PERT so that the researcher proposes that companies can use the CCPM analysis method in scheduling their projects.

References
[1] Babu, A. J. G., & Suresh, N. (1996). Project Management With Time, Cost, and Quality Considerations. European Journal of Operational Research, 88(2), 320–327.
[2] Cottrell, W. D. (2011). Simplified Program Evaluation and Review Technique (PERT), (February), 16–22.
[3] Goldratt, E. (1997). Critical Chain. Great Barrington: North River Press.
[4] Madyatmadja, E. D., Liliana, L., Andry, J. F., & Tannady, H. (2020). Risk Analysis of Human Resource Information Systems Using Cobit 5. Journal of Theoretical and Applied Information Technology, 98(21), 3357-3367.
[5] Leach, L. P. (1999). Critical Chain Project Management Improves Project Performance. Project Management Journal, 30 (2), 39–51.
[6] Leach, L. P. (2005). Critical Chain Project Management 2nd Edition. Artech House. Norwood MA.
[7] Nurprihatin, F., Andry, J.F., & Tannady, H. (2021). Setting the Natural Gas Selling Price Through Pipeline Network Optimization and Project Feasibility Study. International Conference on Science and Technology Applications (ICOSTA) 2020, Journal of Physics: Conference Series.
[8] Nurprihatin, F., Jayadi, E. L., & Tannady, H. (2020). Comparing Heuristic Methods’ Performance For Pure Flow Shop Scheduling Under Certain And Uncertain Demand. Management and Production Engineering Review, 11(2), 50-61.
[9] Nurprihatin, F., Regina, T., & Rembulan, G. D. (2021). Optimizing Rice Distribution Routes in Indonesia Using A Two Step Linear Programming Considering Logistics Costs. International Conference on Science and Technology Applications (ICOSTA) 2020, Journal of Physics: Conference Series.
[10] Nurprihatin, F., Elvina., Rembulan, G. D., Christiano, K., & Hartono, H. (2021). Decision Support System for Truck Scheduling in Logistic Network Through Cross-Docking Strategy. International Conference on Science and Technology Applications (ICOSTA) 2020, Journal of Physics: Conference Series.
[11] Resdiansyah., Darmawan. J., Wijaya, A. H., Hakim, L., & Tannady, H. (2020). Comparing Freeman Chain Code 4 Adjacency Algorithm and LZMA Algorithm in Binary Image Compression. Annual Conference on Science and Technology Research (ACOSTER) 2020, Journal of Physics: Conference Series.
[12] Tannady, H., & Maimury, Y. (2017). Increasing the Efficiency and Productivity in the Production of Low Voltage Switchboard Using Resource Constrained Project Scheduling. Journal of Industrial Engineering and Management (JIEM), 11(01), 01-33.
[13] Tannady, H., & Purwanto, E. (2021). Quality Control of Frame Production Using DMAIC
Method in Plastic PP Corrugated Box Manufacturer. Annual Conference on Science and Technology Research (ACOSTER) 2020, Journal of Physics: Conference Series.

Zarei, S. (2018). Project scheduling for constructing biogas plant using critical path method. Renewable and Sustainable Energy Reviews, 81(May 2017), 756–759.