Optimization of Sei Wampu Dam Project Schedule Using Critical Path Method

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Abstract: There are several companies engaged in construction, EPC (Engineering, Procurement, Construction), Infrastructure Investment, Property, and Real Estate experiencing project delays. One project experiencing delays is Sei Wampu Dam Construction Project, Langkat Regency, North Sumatra Province starting from December 4, 2015 spending cost of IDR 309,093,870,437.59. Based on the data obtained, there was a delay in the project work by 13.575% in the cumulative 10th month results in material losses. Therefore, the project schedule optimization of Sei Wampu Dam is performed. The method used is Critical Path Method (CPM). Based on the calculation, the duration of the lead time is 1136 days with a total cost of IDR 362,200,345.57,-.

1. Introduction
Project management is a project activity applies knowledge, skills, tools and techniques to meet project requirements [1,2,3,4]. Project Management is the application of knowledge, expertise and skills, the best technical and with limited resources, to achieve the goals and objectives that have been determined in order to obtain optimal results in cost performance, quality and time and work safety aspects [5].

A construction project can be said to be successful if it is capable to meet its lead time objectives at the specified time, according to the costs allocated and meet the required quality. Project management is tasked by planning, organizing, leading and controlling existing resources in order to achieve project objectives. There are two tools or techniques for analyzing a development project optimally, namely Gantt Chart and Network Planning [6,7].

The case study discussed in this research is the Sei Wampu Dam Construction Project, Langkat Regency, North Sumatra Province. The project is calculated from 4 December 2015 with an expense of IDR 309,093,870,437.59. Based on data obtained from PT. Adhi Karya Persero Tbk, comparative data between planning and actualization of the Sei Wampu Dam project can be seen in Table 1.

| Time Application (Month) | Progress Planning (%) | Progress Realization (%) |
|--------------------------|-----------------------|--------------------------|
| 1                        | 0.024                 | 0.008                    |
| 2                        | 0.297                 | 0.003                    |
Table 1. Comparison of Planning and Actualization Data (Continued)

| Time Application (Month) | Progress Planning (%) | Progress Realization (%) |
|--------------------------|------------------------|--------------------------|
| 3                        | 0.940                  | 0.006                    |
| 4                        | 0.935                  | 0.120                    |
| 5                        | 2.173                  | 1.125                    |
| 6                        | 6.058                  | 0.787                    |
| 7                        | 2.798                  | 2.679                    |
| 8                        | 1.867                  | 1.462                    |
| 9                        | 2.013                  | 3.021                    |
| 10                       | 4.271                  | 4.364                    |
| **Total**                | **21,555**             | **13,575**               |

Based on Table 1, the process plan with the process realization has a cumulative difference in the 10th month of 13,575%. This is shows that the delays occurrence in project work due to several problems appear during the project work, including delay in material delivery, labor delay, equipment procurement delay, subcontractors delay, incorrect planning, weak project time control, weak coordination, lack of project work supervision, lack of technical personnel, weak communication, and others.

To overcome the project schedule delay, an optimization of the project schedule is carried out using the Critical Path Method (CPM).

2. Methodology

The study was conducted on the Sei Wampu Dam construction project in Langkat Regency. The study was conducted by direct observation in the field and conducting interviews with employees in the field. From the immediate observation, the problem formulation is determined based on conditions so that the research objectives can be applied. The purpose of the research specified is the solution to the problem that occurs. Furthermore, data collection is required as an input to resolve the project schedule issue. Based on this data, problem analysis occurs. The analysis is carried out with several stages, namely the making of a SIPOC (Supplier-Input-Process-Output-Customer) diagram and the critical path calculation using the Critical Path Method (CPM). The SIPOC diagram is useful to know the processes involved, the sequence of processes and interactions between processes, and what materials are involved in the process. While the critical path calculation is done to determine the minimum lead time project. The critical path calculation is done by forward calculation, backward calculation, and total float calculation at each activity on the project. By calculating the total float, a critical path and project duration work will be obtained.

2.1. Critical Path Method (CPM)

CPM is a deterministic technique uses a dependencies network between tasks and deterministic values given for the task duration, the critical path calculation which is the minimum time of lead time [8]. CPM provides parameters considered on each activity including the quickest start and end time, last start and end time, and the delay [1,9,10]. The most important advantage of CPM is it allows facilitating the optimization models usage for time estimation and costs and for sequentially [11,12]. To list the activities needed to finish the project with the duration at each activity and dependence at each activity, scheduling critical paths for network activity on nodes can be formulated, mathematically. ES (i) is the earliest activity start time for activity i, EF (i) is the earliest activity finish time for activity i, LS (i) is the latest start for activity i and LF (i) is the latest finish for activity i. Calculations relevant to nodes ie forward calculations (running from the first to the last), and countdowns (running from the last back to the first node in the network) is presented as follows:

Stage 1: Initial activities numbered by 0.
Stage 2: The next number assigned to the numbered activity which is the previous activity has been numbered. Stage 2 repeated by until all activities are numbered [10].

3. Result and Discussion

3.1. SIPOC Diagram (Supplier-Input-Process-Output-Customer)

SIPOC Diagram is a tool used by the team to identify all relevant elements of the project upgrade process before the work starts. This helps define complex projects that may not have good coverage, and are typically used in the Measure phase of the Six Sigma DMAIC methodology (Define, Measure, Analyze, Improve, Improve, Control). The tool name asks the team to consider the supplier (‘s ’ in SIPOC) of your process, input (‘ I ’) into the process, the process (‘ P ’) your team improves, the output (‘ O ’) of the process, and the customer (‘ C ’) that receives the process output. In some cases, customer requirements may be added to the end of SIPOC for further details. The SIPOC diagram of Sei Wampu Dam project can be seen in Figure 1.

Based on the diagram above, it can be seen the components in the project and the relationship between existing components.

3.2. Calculation of Critical Path

Critical activity is the minimum lead time project. If there is a delay in activities of the critical path it will result in an increase all of project duration. Project network analysis is carried out to obtain critical path on the project network.
3.2.1. Forward Calculation
Activity A is not preceded by any activity, then:

- **Early Start** \((ES)_{(1,2)} = 0\), so that **Early Finish** \((EF)_{(1,2)}\):
  \[\begin{align*}
  EF_{(1,2)} &= ES_{(1,2)} + D_{(1)} \\
  EF_{(1,2)} &= 0 + 180 \\
  EF_{(1,2)} &= 180
  \end{align*}\]

The calculation continues for all activities.

3.2.2. Backward Calculation
BW activities do not precede any activities, then:

- **Lastest Start** \((LS)_{(104,105)} = 1116\), so that **Lastest Finish** \((LF)_{(104,105)}\):
  \[\begin{align*}
  LF_{(104,105)} &= LS_{(104,105)} + D_{(105)} \\
  LF_{(104,105)} &= 1116 + 20 \\
  LF_{(104,105)} &= 1136
  \end{align*}\]

The calculation continues for all activities.

3.2.3. Calculation of Total Float
In activity A, the total float calculation is performed:

\[\begin{align*}
  TF_{(A)} &= LF_{(A)} - ES_{(A)} - D_{(A)} \\
  TF_{(A)} &= 180 - 0 - 180 \\
  TF_{(A)} &= 0
  \end{align*}\]

The calculation continues for all activities.

Based on the results of forward calculations, backwards calculations, and total float, a project critical path is carried out: A-C-D-E-I-J-AA-d8-AC-d9-AD-AE-AF-AG-AI-AJ-d11-AL-AM-BO-BP-BQ-BR-BW dan A-C-D-E-I-J-AA-d8-AC-d9-AD-AE-AF-AG-AH-d10-AJ-d11-AL-AM-BO-BS-BT-BU-BW with a total lead time of 1136 days. The project critical path can be seen in Figure 2.

![Critical Path of Sei Wampu Dam Project](image)

**Figure 2.** Critical Path of Sei Wampu Dam Project

3.3. Calculation of Project Cost
The activities description of Sei Wampu Dam construction has a critical path = A-C-D-E-I-J-AA-d8-AC-d9-AD-AE-AF-AG-AH-AI-d10-AJ-d11-AL-AM-d19-BO-BP-BQ-BR-BS-BT-BU-d27-d28-BW.

- **Lead Time** = 1136 days
- **Total Cost** = Direct cost + Indirect cost = IDR 309,093,870.438 + (1136 × 17,763.355)
PPN (10%) = 10% × IDR 329.273.041.415 = IDR 32.927.304.142

Total Cost (include PPN) = IDR 329.273.041.415 + IDR 32.927.304.142 = IDR 362.200.345.557

4. Conclusion
The problem of project delays in Sei Wampu Dam Construction can be overcome by using Critical Path Method (CPM). Based on the calculations result using CPM obtained that lead time of Sei Wampu Dam project is 1136 working days from December 4, 2015 with a total cost of IDR 362.200.345.557.

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