ABSTRACT

In the MSTB T-701D Crude Oil Storage Tank project, good scheduling is needed so that the project can run smoothly during the process. The most frequently used methods in designing project scheduling are the Critical Path Method and the Critical Chain Project Management. This study aims to compare scheduling results between the traditional CPM and the CCPM methods. The project used in this research analysis is the Crude Oil Storage Tank MSTB T-701D project. The Root Square Error Method (RSEM) is used to find the buffer size. In the scheduling analysis, calculations are carried out manually and with the help of Primavera P6 software as validation for calculating the total float, critical path, and project network. Project scheduling using the Critical Path Method (CPM) is known to be completed in 164 days. Whereas for the CCPM, the project can be completed in 140.1 days plus the RSEM buffer calculation method of 5.29 days, and the total scheduling with CCPM produces 145.3 days. This analysis shows that the traditional CPM method has a larger estimated duration than CCPM with an RSEM sizing buffer. Then a suggestion was made to work on the MSTB T-701D Crude Oil Storage Tank project using the CCPM and RCA methods.

Keywords: Critical Path Method, Critical Chain Project Management, Root Cause Analysis
1. INTRODUCTION

Planning and scheduling is an integral part of determining the success of a project. Scheduling a project needs to be considered in project management to determine the duration of work and what activities are in the project, as well as indicating the time and sequence of project activities so that a logical and realistic schedule is formed (Hidayah, Ridwan, and Cahyo, 2018). Product supply activities have a series of processes before producing a product, from providing raw materials, material processing, production, packaging, and quality control to distributing these products to consumers. So at each stage, it takes labor and costs. Every company always strives for every process that is carried out to run effectively and efficiently so that the benefits that the company gets can be optimal (Waluyo and Pulansari, 2014).

However, often a project experiences delays in the completion process. Poor project time management can cause this (Rio and Herawati, 2022). For the smooth running of a project, management is needed who will manage the project from start to finish, namely project management (Priyanto, Ervadius, and Wahyudi, 2019). Project management is the application of knowledge, skills, tools, and work methods in project activities to meet project requirements (Utamadan and Syairudin, 2020). The main objective of project management is for projects to be implemented efficiently, on time, and to achieve the desired results. Therefore, the role of planning in a project is significant. Everything must start with a plan and be mutually agreed upon between the stakeholders involved in the project (Putri and Bobby, 2020).

PT. XYZ is a company that provides project services in EPC (Engineering, Procurement, and Construction). The EPC (Engineering, Procurement and Construction) project is a type of project that also has the complexity of a construction project, starting from the interdependence between existing activities, overlapping phases between each activity, breaking down activities into more detailed work activities, complexity organizational structure and claims in predictions that arise during the implementation period (Kabirifar and Mojtahedi, 2019). Projects—one of the EPC projects undertaken by PT. XYZ is the Crude Oil Storage Tank MSTB T-701D project. The MSTB T-701D Crude Oil Storage Tank project is a project for making oil tanks with a wholesale work system. The MSTB T-701D Crude Oil Storage Tank project, which is the object of research, has not implemented a good project management concept. Where the engineering activities are not by the schedule (late) of the project plan from the original 21 days to 47 days. Therefore scheduling must be controlled properly and correctly. Because if the engineering activities are delayed, or late, the procurement work can also experience delays.

This inefficient project management concept is influenced by scheduling which still uses conventional or manual Microsoft Excel methods. This manual method is considered ineffective because the project experiences a delay of 13% in engineering activities and can cause losses to the project. The method can be inefficient because the project scheduling process does not consider the relationship between activities and does not explain the critical path of the MSTB T-701D Crude Oil Storage Tank project, which is the object of research. The critical way is the most extended series of activities that must be completed on time to complete the project. Therefore, in this final project, research is carried out using a scheduling method that is much more efficient and optimal when compared to the manual scheduling method. Most of the previous research was conducted on maritime companies for ship repair. No research has ever been conducted focusing mainly on fabrication, design, and construction companies.

The Critical Path Method (CPM) method is a method that is often used in scheduling activities in project management. The CPM method considers the actions required to complete a project and its duration and plans the workforce requirements for a project (Febriana and Aziz, 2021). The CPM method also adds safety time when scheduling time to reduce the risk of delays in a project. However, over time, a new method emerged, namely the Critical Chain Project Management (CCPM) method. Therefore, the authors want to compare the Critical Path Method (CPM) and Critical Chain
The Critical Chain Project Management (CCPM) method is used to design and manage projects that focus on the resource requirements for implementing the project. By eliminating safety time, CCPM replaces it by adding buffer time or backup time. This buffer time focuses on completing the project's critical chain. Based on Rizky's research (2022), they were told that the CCPM method replaces safety time with buffer time to guarantee critical chains on time. Buffer time consists of a feeding buffer and a project buffer. These two Buffer times ensure the project schedule's critical chain and integrity (Sugiyanto and Insan, 2022). The most frequently used method is the Root Square Error Method (RSEM) to find the quantity of the feeding buffer and project buffer. In project management science, many techniques are commonly used to solve a problem, including the Critical Path Method (CPM) and Critical Chain Project Management (CCPM) methods (Haryoko et al., 2022).

Delays in project work can become a problem if it cannot be managed and controlled correctly. One of the methods to identify the causes of delays in project work and project control is the Root Cause Analysis (RCA) method with fishbone diagrams to identify the causes of delays in project work based on the 5M model (machine, method, material, manpower or man, and mother of nature) to identify the root cause of the delay in project execution (Al-Zwainy, Mohammed and Varouqa, 2018). The application of RCA is expected to help companies to be able to find out the root causes of events that cause delays in project work (Utamadan and Syairudin, 2020).

Based on the background description above, the author will conduct a scheduling analysis for the Crude Oil Storage Tank MSTB T-701D project at PT. XYZ. The object of research in this final project is scheduling the fabrication and installation processes of the Crude Oil Storage Tank MSTB T-701D project. The methods used are the Critical Path Method (CPM) and Critical Chain Project Management (CCPM) to conduct the scheduling analysis. This research provided a new scheduling option to reduce the risk of delays in the MSTB T-701D Crude Oil Storage Tank project.

2. METHODS

2.1 Problem Identification

Problem identification is carried out to find and identify problems in the field. It is done by discussing with the supervisor so that the problem formulation can be found.

2.2 CPM Method Scheduling

The Crude Oil Storage Tank MSTB T-701D project data will be processed using the critical path (CPM) method. The first stage is to create a project network from the Crude Oil Storage Tank MSTB T-701D project work data. Network Planning following the work breakdown structure of the crude oil storage tank project obtained from company data. Next, determine the critical path using the forward and backward calculation methods to get the critical path and total float or project duration (Bachmid, Fatmah Arsal and Yaqin Nur, 2020).

2.3 CCPM Method Scheduling

Each activity's safety time will be estimated after identifying the critical path in the CPM method. Furthermore, safety time is eliminated to maximize the productivity of workers. After stopping safety time from each activity, the next step is to calculate the size of the buffer to replace safety time. Next is to calculate the project buffer (Dashti et al., 2021). The value is the average total safety time wasted from each activity. Another method is to use the Root Square Error Method (RSEM) by calculating two standard deviations. After entering the project buffer, entering the feeding buffer protects the critical path from delays. The method used to determine it is the same as the project buffer, utilizing the root square error method (RSEM) but only limited to the safety time on the critical path. The result will be placed at the end of the critical path when it meets the critical path (Dzulfitro Tampubolon, Rahman and Haryanto, 2021).

2.4 Root Cause Analysis (RCA)

Root cause analysis diagram as a problem-solving tool, namely a fishbone diagram or fishbone diagram. A fishbone diagram is used to find the causal factors of a characteristic deviation and
clearly illustrates the various sources of nonconformities in related products. The principle used to make a cause-and-effect diagram is brainstorming (Ganda, 2021).

3. FINDINGS AND DISCUSSION

3.1. Findings

This study uses the CPM and CCPM methods to minimize project delays. Based on primary data obtained from the company, it is known that there are 133 types of work activities to complete the project, where all work is categorized into seven job categories, namely Contract Award, Kick Off Meeting, Engineering, Procurement, Shop Fabrication, and Testing, Delivery and Mobilization, Installation, Demobilization.

Table 1. Project Activities of Crude Oil Storage Tank MISTB T-701D project

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3.2. Discussion

3.2.1. Developing Network Planning with the CPM Method

Compiling a CPM network planning results in finding the critical path of all project activities. The critical path consists of several activities with a total float value of less than or equal to zero. To find the result of the total float required forward and backward calculations (Stie, Tuban and Syaikhudin, 2020).

1) CPM Forward Calculation
Forward calculations find ES (Earliest Start) and EF (Early Finish) results. The data required in the forward analysis is the predecessor data from the project. If an activity has more than one predecessor, the most considerable predecessor time is taken. The equation used in the forward calculation is as follows (Arifin and Shadiq, 2019).

\[ EF(i-j) = ES(i-j) + D(i-j) \]  

(1)

2) CPM Backward Calculation
The backward calculation finds the results of the LS (Latest Start) and LF (Latest Finish). The data needed in the countdown is the successor data from the project. If an activity has more than one successor, the smallest successor is taken. The equation used in the forward calculation is as follows (Handayan i, Mona and Pebriyanto, 2019).

\[ LS(i-j) = LF(i-j) + D(i-j) \]  

(2)

3) CPM Total Float Calculation
The total float of an activity can be calculated using the latest finish time (LF) minus the earliest finish time (EF). The characteristics of an activity on a critical path or critical path can be known if the total float of an activity is the same as where the activity cannot be postponed. Total float can be found using the following formula (Shadiq, 2020):

\[ TF = LF - EF \]  

(3)
Based on the calculation of the total float in Table 2, the critical path of the MSTB T-701D Crude Oil Storage Tank manufacturing project can be identified. Activities included in the critical path have a total float result equal to or less than zero. In this case, the activities included in the critical path have a total value of float = 0. The activities that are on the critical path are 1, 2, 4, 7, 21, 22, 24, 25, 26, 27, 28, 57, 58, 59, 60, 61, 62, 83, 93, 95, 96, 98, 99, 101, 102, 103, 105, 106, 108, 109, 114, 115, 117, 118, 123, 124, 132, 133 with the total duration of the total project is 164 days.

### 3.2.2. Application of the CPM Method in Primavera Software

The first step that must be taken in applying the method to the Primavera P6 software is to enter the data that has been obtained. The data that needs to be entered into the Primavera P6 software is the activity name, activity duration, and predecessor. In implementing scheduling on the Primavera P6, the initial steps taken were to enter the project start date and determine the calendar that corresponds to the docking work of the MSTB T-701D Crude Oil Storage Tank project, namely seven working days with 9 hours of working time. Activities on the critical path can be seen in the Primavera P6 software with a red box on the Gantt chart. Another way to find the critical path is to add the total float and critical columns. If an activity is on the critical path, it has a total float = 0 and the statement "YES" in the critical column. The use of the Primavera P6 software has the objective of validating forward manual calculations, reverse manual calculations, and manual total float calculations. The following output image generated by the software is shown in Figure 1.

**Figure 1. Input data on the Primavera P6 software**

### 3.2.3. Developing Network Planning with the CCPM Method

1) Cutting Safety Time in Activities

Based on interviews with Project Control Staff data on cutting the duration of safety time in 7 job categories, namely Contract Award and Kick Off Meeting activities by 0%, Engineering, Procurement, and Shop Fabrication and Testing by 10%, Delivery and Mobilization by 20%, Installation and Demobilization by 15%.

2) Buffer Calculation

In the CCPM method, the duration of safety time is cut to minimize work duration and maximize existing work. However, cutting the duration also increases the risk of delays. So in the CCPM method, a buffer replaces the loss of safety time in activities(Sugiyanto and Insan, 2022). There are two types of buffers used in CCPM. Project buffer to protect the entire project chain placed at the end of the project chain and feeding buffer to protect critical path activities from delays in activities on non-critical paths set at the end of the non-critical chain that will meet the critical chain(Lianto and Anondho, 2018). The method used to find buffers in this final project is the Root Square Error Method (RSEM). The author uses the RSEM method, considering that the buffer duration results obtained from RSEM are relatively minor compared to other buffer sizing.
methods. The equation used is as follows (Hasil et al., 2023).

\[(Ui) = Si - di\]  
Buffer sizing = \[\sqrt{\sum_{i=1}^{n}(U_i)^2}\]  

Definition:

- a) \(U_i\) = Uncertainty of work duration \(i\)
- b) \(Si\) = Estimated uncertainty of work with safety time \(i\)
- c) \(di\) = Estimated duration of work without safety time \(i\)
- d) \(n\) = Lots of work

The project buffer and feeding buffer results in the CCPM method can be obtained as follows.

**Table 3. Feeding Buffers**

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**TOTAL** \[25,235\]

**FEEDING BUFFER (DAYS)** \[5.02\]

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| PROJECT BUFFERS |
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| 108             | 2      | 1.7    | 0.3             |
| 109             | 3      | 2.55   | 0.45            |
| 111             | 2      | 1.7    | 0.3             |
| 112             | 3      | 2.55   | 0.45            |
| 114             | 3      | 2.55   | 0.45            |
| 115             | 2      | 1.7    | 0.3             |
| 117             | 2      | 1.7    | 0.3             |
| 118             | 3      | 2.55   | 0.45            |
| 120             | 3      | 2.55   | 0.45            |
| 121             | 2      | 1.7    | 0.3             |
| 123             | 3      | 2.55   | 0.45            |
| 124             | 2      | 1.7    | 0.3             |
| 126             | 3      | 2.55   | 0.45            |
| 127             | 2      | 1.7    | 0.3             |
| 129             | 2      | 1.7    | 0.3             |
| 130             | 2      | 1.7    | 0.3             |

| TOTAL | 25,235 |

| FEEDING BUFFER (DAYS) | 5.02 |
3) CCPM Forward Calculation
Forward calculations find ES (Earliest Start) and EF (Early Finish) results. The data required in the forward calculation is the predecessor data from the project. If an activity has more than one predecessor, the most significant predecessor time is taken. The equation used in the forward calculation is as follows (Azhari et al., 2021).

\[ \text{EF}(i-j) = \text{ES}(i-j) + D(i-j) \]  

4) CCPM Backward Calculation
The backward calculation finds the results of the LS (Latest Start) and LF (Latest Finish). The data needed in the countdown is the successor data from the project. If an activity has more than one successor, the smallest successor is taken. The equation used in the forward calculation is as follows (Andiyan et al., 2021).

\[ \text{LS}(i-j) = \text{LF}(i-j) + D(i-j) \]  

5) CCPM Total Float Calculation
The total float of an activity can be calculated using the latest finish time (LF) minus the earliest finish time (EF). The characteristics of an activity on a critical path or critical path can be known if the total float of an activity is the same as where the activity cannot be postponed. Total float can be found using the following formula (Sinaga and Husin, 2021):

\[ \text{TF} = \text{LF} - \text{EF} \]  

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Based on the calculation of the total float in Table 2, the critical path of the MSTB T-701D Crude Oil Storage Tank manufacturing project can be identified. Activities included in the critical path have a total float result equal to or less than zero. In this case, the activities included in the critical path have a total value of float = 0. The activities that are on the critical path are 1, 2, 4, 7, 21, 22, 24, 25, 26, 27, 28, 57, 58, 59, 60, 61, 62, 83, 93, 95, 96, 98, 99, 101, 102, 103, 105, 106, 108, 109, 114, 115, 117, 118, 123, 124, 132, 133 with the total duration of the total project is 140.1 days. If the buffer is fully used, then the duration will be 145.3.

### 3.2.4. Application of the CCPM Method in Primavera Software

The CCPM method is the same as overall data input as the CPM method. The first step that must be taken in applying the method to the Primavera P6 software is to enter the data that has been obtained. The data that needs to be entered into the Primavera P6 software is the activity name, activity duration, and predecessor. Reducing the period of each activity in this...
method causes a more significant risk of delay. Therefore, a buffer or buffer time must be applied to prevent late activities. Buffers must be applied to project time with reduced activity duration to produce a safer schedule. In the process using Primavera P6, entering the buffer value is divided into two stages. The first is joining the value of the feeding buffer, which is placed at the end of the activity on the non-critical path, and the second stage is the project buffer placed at the end of the activity on the critical path in the Primavera P6. The following input data and buffer in the software are shown in Figure 2.

![Image of input buffer in Primavera P6 software]

**Figure 2. Input buffer in the Primavera P6 software**

### 3.2.5. Buffer Management Analysis

Based on previous calculations and analysis, it was found that the size of the project buffer was 5.29 days. These results will then be divided into three equal measures, which will determine the areas as shown in the table below:

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<th>Duration Used (Days)</th>
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<td>There is no action to be taken</td>
</tr>
<tr>
<td>34% - 66%</td>
<td>1.8 – 3.5</td>
<td>Plan preventive actions</td>
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<tr>
<td>68% - 100%</td>
<td>3.6 – 5.29</td>
<td>Implement precautions</td>
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Based on Table 5, the additional duration is in the zone of consumption of the buffer 0% -33%, the time used or the addition of working days is 1.7 working days and is categorized as no action to be taken on the project because it is still in a safe condition, for the consumption zone the buffer is 34% - 66% duration used or additional working days of 3.5 working days categorized as necessary
to plan preventive actions on the project because it increases the burden of project costs through increased duration while for the buffer consumption zone, 67% - 100% duration used or additional working days of 5.29 days work categorized as the need to apply preventive measures because it results in swelling or increasing the burden of project costs through an increase in 5.29 days.

### 3.2.6. Root Cause Analysis (RCA)

One method for identifying the causes of delays in project work and project control is the Root Cause Analysis (RCA) method with cause-and-effect diagrams to identify the causes of delays in project work based on the 5M model (Machine, Method, Material, Man Power or Man, and Mother Nature or Environment). Factors causing delays in the MSTB T-701D Crude Oil Storage Tank manufacturing project were found by brainstorming and grouped into a Fishbone diagram, as shown in Figure 4.

![Image of Fishbone Analysis Diagram]

**Figure 4. Fishbone Analysis Diagram**

1) **Man**

   a. **Worker Competency**

   A worker's skill determines the productivity and efficiency of fabrication and installation activities; the more skilled and responsive, the more productive. Because this is related to skills in marking, cutting, welding, and painting activities, another factor that affects the workers' competence is worker fatigue, which directly impacts the competence of the workers.

   b. **Hours Factor**

   Shift changes often run irregularly, which results in a direct increase in Idle Time because the loading and unloading activities cannot run. The most common thing is that the workforce ends the shift earlier than it should, resulting in frequent ineffective loading and unloading.
activities before the shift change.
c. Low Labor Productivity
Based on the results of interviews with workers, the cause of project delays was the behavior of unskilled workers who lacked discipline and did not produce work according to the owner's will. As a result, work handover takes longer due to improvements to work items that have been completed. This is due to the lack of inspections and directions in the field that should be carried out by supervisory consultants and supervisors from contractors regarding the work to be carried out.

2) Machine
a. Constraints on CNC and Plasma Cutting
In marking and cutting activities, of course, the role of CNC and plasma cutting is very necessary and is always used non-stop in making patterns and cutting materials so that the condition of CNC and plasma cutting also requires maintenance to keep the machine in good condition. The maintenance process is often not scheduled regularly, so several cases of damaged CNC and plasma cutting occur.
b. Obstacles to Welding Machine
From the results of observations made, the production capacity of the welding machine because was found that the machine is old. Even though its function is still running well, its performance has certainly experienced degradation. The machine can experience a stop at any time in the middle of production. Thus, these constraints will be increasingly difficult to achieve promptly.
c. Fleet Constraints
From the results of observations made, the lack of maintenance of the fleet is also one of the factors that influenced the failure to achieve the estimated duration due to material and equipment mobilization project activities where the author made observations in the field and found several cases of damage to trucks which were due to lack of maintenance on trucks operating in the area.
d. Obstacles on Head Crane
From the results of the observations made, the removal and lifting of material that exceeds capacity cause damage to head cranes. As a result of damage to the head cranes, the movement of materials becomes hampered, thereby reducing the productivity of the workforce that has been deployed.

3) Material
a. Incomplete Materials
From the results of observations, the material affects production capacity if it is found that the raw material is incomplete during the production schedule, so the production process is on hold due to waiting for the completeness of the raw material. Thus, the entirety of raw materials will be increasingly difficult to achieve promptly to support the fabrication process.
b. Materials Delay
From the results of observations, the cause of delays in the project is the delay in the arrival of materials such as components that have not been ordered or are currently in production. For component goods that have not been produced, it is likely because the supplier is still looking for raw materials to make these goods, which also requires several stages of procurement of goods that need to be passed.

4) Method
a. Conventional Scheduling Method
From the results of observations made, the cause of delays is due to inefficient scheduling methods that still use conventional or manual methods using Microsoft Excel. The method can be less efficient because the project scheduling process does not consider the relationship between activities and does not explain the project's critical path.
b. Not according to procedure
From the results of observations made, the cause of delays in terms of the method is that the welding current and welding speed used are not adjusted to the Welding Procedure Specification when carrying out welding activities which are too large and cause repetition of welding on the tank parts so that further activities are delayed.

5) Mother Nature or Environment
a. Room temperature
From the results of observations made based on conditions in the field, the room temperature in the factory environment, which is hot and less extensive, causes workers to make tank parts feel uncomfortable in doing their job and interfere with employee mobility, causing a lack of efficiency and effectiveness at work.
b. Lighting in the Room
From the observations made based on conditions in the field, room lighting makes workers less focused on following the path to be welded, which results in over-limit welding or the weld going off the path that must be welded.
c. Bad weather
delivery and mobilization activities often experience problems due to bad weather. Bad weather, such as rainstorms and big waves at sea, can hinder the shipping process. However, the weather factor is difficult to predict, making it difficult to control.

Based on the problems faced by PT. XYZ was working on the MSTB T-701D Crude Oil Storage Tank manufacturing project; a suggestion was given to use the CCPM and RCA methods and document learning and project knowledge as a guide to achieving success in the project through improving project performance so that the company can complete the project by the work contract agreed upon with the project owner.

4. CONCLUSION AND SUGGESTION

4.1. Conclusion

Based on the results of the scheduling analysis on the Crude Oil Storage Tank MSTB T-701D project at PT. XYZ uses the CPM, CCPM, and Fishbone diagram methods. The following conclusions are obtained:

The resulting duration based on scheduling using the CCPM (Critical Chain Project Management) method is 145.3 days, 18 days faster, which is 11% compared to the company and CPM methods, which is 164 days. Based on the results of field observations, reference data, and fishbone diagram analysis, it can be concluded that the factors causing the delay in the MSTB T-701D Crude Oil Storage Tank manufacturing project include man (Worker Competence, Working Hours Factor, and Low Labor Productivity), machine (Constraints on CNC and Plasma Cutting, Obstacles on Welding Machine, Fleet Constraints, and Head Crane Constraints), material (Incomplete Material and Material Delay), method (Conventional and Non-Procedural Scheduling Methods), and mother-of-nature (Room Temperature, Room Lighting, Bad Weather).

4.2. Suggestions

Companies can apply the CCPM schedule in scheduling subsequent projects accompanied by the company's socializing, training, and control efforts.

References


PATH METHOD) PADA PROYEK KONTRAKTOR ALUMINIUM DAN KACA (Studi Kasus Pembangunan Auditorium), JURNAL TEKNOMAIN, 18(3). https://doi.org/10.33087/civronlit.v4i1.44.


