Research on a Project Schedule of Factory Renovation for Manufacturing Plants in Bandung

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Abstract. Renovating a plant facility is an example of a project. It is a complex process that the project needs to complete all the task while ensuring the operations without disruption. In project management, scheduling and cost optimization are two main operation problems. These correlate with each other and have proven mathematical solutions for the basics. In this study, the case study faced was to prepare a schedule plan in the process of renovating factory facilities. The facilities to be renovated are based on 2 main facilities, namely Production office facilities and Fabrication plant facilities. The implementation of the renovation of the 2 facilities has constraints in the time available. With the CCPM approach, this study proposes a schedule for implementing renovation projects with limited availability of time. The results obtained; this factory facility renovation project is scheduled to be completed less than 40 calendar days.

1. Introduction

A project is a temporary effort to create a unique product, service, or result. Project management is the implementation of knowledge, skills, tools, and techniques to project activities to satisfy the project requirements [1]. Uncertainty is one reason to differentiate project management as a separate field of knowledge. The project duration and its success are affected by the way the uncertainty is managed in the project (and risk management in particular). According to some studies conducted for the traditional project management methods, only 44% of the projects are completed in time. Of the total projects, 70% of them decrease the amount of planned work, while the rest end without being realized[2].

Every work on the project will deal with the risks that must be faced. The risk that can occur when working on a project is the delay. According to [3], the delay in project execution in general can be caused by several factors including labor, materials (equipment), equipment, site characteristics (site characteristics), managerial (managerial), financial (financial), factors Others include the intensity of rainfall, economic conditions, and workplace accidents. Delays or discrepancies in the timing of a project can have a negative impact on the project being carried out. The most likely thing to happen is the increase in the cost of working on a project / over budget and will cause demands from project owners who want a timely settlement. If there is a change in time or delay in the execution of a project, then the budget is also changed, therefore the accuracy of the time in the project is very important.

Project scheduling is the utilization of skills, techniques, and intuition obtained through the combination of knowledge and experience to present a framework for schedule model creation as well as to evolve effective schedule models [4]. The precedence diagram method (PDM), Critical Path Method (CPM), and Critical Chain are the most common scheduling methods, supported by all the major
scheduling tools [1]. Particularly, Critical Chain Project Management (CCPM) focuses on the limitation of project resource and requires some flexibility in order to keep the project in its time borders [2]. This is a project planning and management method that places the major emphasis on the resources required to undertake project tasks [5]. It can be applied both in a single project and multi-project structures where resources are being used in several projects concurrently [6].

In the current field of project management, a scheduling method is used to handle unpredictability as well as negative effects on project accomplishment and other projects without the need to add resources. This method is known as the Critical Chain Project Management method. Critical Chain is a method for designing and managing projects that focus on the resource requirements to conduct the project, for which the Critical Chain has been positioned differently from the Critical Path and PERT methods, which emphasizes work orders and scheduling.

Buffers are added to the duration used in project scheduling to cover the critical chain for the success of the project, in the critical chain project management method. There are many factors that influence the size of a project buffer, there are risk factors as follows: disruptions in material and tool supplies, irregular financing, design errors, bad weather, equipment damage, inefficient contractors, legitimate administrative disruptions, etc. According to [7], buffer management is the key to managing activities in the critical chain of project schedules. To complete the project earlier than the planned schedule with resource constraints, the buffer in the Critical Chain is used to solve the problem. The buffers used in the critical chain are as follows: 1. Project buffers are to prevent the project’s final completion time from the schedule uncertainty in critical chain activities; 2. In order to protect and maintain the performance of critical chain network activities from change due to the schedule uncertainty in activities from non-critical networks so as not to interfere with activities in critical networks in a dependency relationship, feeding buffers are required; and 3. Resource buffers are to anticipate and guarantee the security of the availability of the resources so that there is no additional time for the critical chain.

According to [8], one approach that is often used in determining the buffer size is simple to determine the project buffer and feeder buffer, namely cut and paste method (C & PM). This cut and paste (C&PM) method is an adhesive rule used to determine project buffers and feeding buffers in C&PM basically cuts 50%, 40%, 30%, 20%, or 10% of the duration for all activities, and attaches project buffers by half.
the critical chain at the end chain, as well as attaching a buffer with half the duration of activity to activities on a path that is not a critical (non-critical) chain that leads to a critical chain.

It is often assumed that renovation projects are simply a special type of new construction in the construction industry. They are often arranged in the same way, although mostly with a more traditional division of labor and contract forms, and lack of standardization. However, there are a number of dissimilarities between the process of new building and renovation projects [9]. Renovation is connected with improvement and rehabilitation for restoring [10].

This research is conducted in a company engaged in manufacturing for electronic equipment in Bandung. Production development requires the company to increase its production capacity. Thus, the company plans to renovate an old plant with a larger capacity, which is owned by the parent company. In order to renovate the plant facility, this study aims to proposes a developed project scheduling utilizing CCPM. The planned schedule using a common technique is compared with the result showed in CCPM. These outputs can assist the company to determine the project schedule for the renovation planning process in order to avoid project delay.

2. Methodology

CCPM is defined as a sequence of critical tasks whose duration influences the overall duration of the project. It concentrates on the project completion date as the only important date.

As illustration, Fig. 2 shows the critical path of a project, then by using C&PM approach, each activity is simulated to be deducted with 50%, 40%, 30%, 20%, or 10% of the duration.

The example of the calculation from each activity (A – E) after we implement C&PM. Activity A, with the default duration is 4 (unit of time), and then we use C&PM 40%, 30%, 20%, or 10% so the remaining duration is:

\[
\begin{align*}
A(C50) &= 4 \times 50\% = 2 \\
\text{Remaining duration is} &= 4 - 2 = 2 \\
A(C40) &= 4 \times 40\% = 1,6 \\
\text{Remaining duration is} &= 4 - 1.6 = 2.4 \approx 2 \\
A(C30) &= 4 \times 30\% = 1,2 \\
\text{Remaining duration is} &= 4 - 1.2 = 2.8 \approx 3 \\
A(C20) &= 4 \times 20\% = 0,8 \\
\text{Remaining duration is} &= 4 - 0.8 = 3.2 \approx 3 \\
A(C10) &= 4 \times 10\% = 0,4 \\
\text{Remaining duration is} &= 4 - 0.4 = 3.6 \approx 4
\end{align*}
\]
All the calculation use roundup or round down, to get better time unit calculation. The result from each activity are shown in Table I.

| Activity | The remaining duration of activity using C&PM |
|----------|-----------------------------------------------|
|          | C50   | C40   | C30 | C20 | C10 |
| A        | 2     | 2     | 3   | 3   | 4   |
| B        | 3     | 3     | 4   | 4   | 5   |
| C        | 1     | 1     | 1   | 2   | 2   |
| D        | 2     | 2     | 2   | 2   | 3   |
| E        | 4     | 4     | 5   | 6   | 7   |

### 3. Result and Discussion

#### 3.1. Coordinate the sequence of projects

Based on the CCPM concept [2], project resources are divided into two categories as follows: critical and non-critical task resources. In this study, the important tasks related to resources are arranged, since they directly affected the overall duration and success of the project. Then, it is required to ensure the availability of resources needed for the next task when several tasks on the critical path are completed.

| Task Code | TASK                  | DAYS |
|-----------|-----------------------|------|
| A         | [Production Office]   |      |
| A1        | [Mobilization]        | 1    |
| A2        | [Destruction]         | 1    |
| A3        | [Clean up]            | 1    |
| A4        | [Floor-job]           | 8    |
| A5        | [Wall-job]            | 4    |
| A6        | [Frame and door]      | 4    |
| A7        | [Stair railing]       | 4    |
| A8        | [ceilings and stairs] | 4    |
| A9        | [Painting]            | 8    |
| A10       | [Company logo-job]    | 4    |
| A11       | [Furniture-job]       | 4    |
| B         | [Fabrication Plant]   |      |
| B1        | [Destruction]         | 1    |
| B2        | [Clean up]            | 1    |
| B3        | [Wall-job]            | 9    |
Based on WBS data in Table II, it can be seen that the task series on site 1 (Production Office) and site 2 (Fabrication Plant) have almost the same set of tasks. From the list of tasks, we arranged which tasks are important and are directly related to the availability of resources. After taking some interview with the project team, we separated the task based on the importance level of the project. Table III presents the list of the task with a high importance level.

| Task Code | TASK               | DAYS |
|-----------|--------------------|------|
| B4        | [Frame and door]   | 5    |
| B5        | [Ceilings and stairs] | 9    |
| B6        | [Painting job]     | 9    |
| B7        | [Company logo-job] | 4    |
| B8        | [Waterproofing]    | 9    |

### Table 3. Important Task

| Task Code | Important Task          |
|-----------|-------------------------|
| A         | [Production Office]     |
| A4        | [Floor-job]             |
| A9        | [Painting]              |
| B         | [Fabrication Plant]     |
| B3        | [Wall-job]              |
| B5        | [Ceilings and stairs]   |
| B6        | [Painting job]          |
| B8        | [Waterproofing]         |

### Table 4. Detailed Important Task

| Task Code | Importance Task          | Duration (days) | C&PM C25 |
|-----------|--------------------------|-----------------|----------|
| A         | [Production Office]      | 8               | 6        |
| A4        | [Floor-job]              | 8               | 6        |
| A9        | [Painting]               | 8               | 6        |
| B         | [Fabrication Plant]      | 9               | 7        |
| B3        | [Wall-job]               | 9               | 7        |

### 3.2. Time planning of the project implementation

The next step of the critical chain method is to plan a safety time for the project in order to ensure that the planned time has not been wasted. It is also to assure the project runs as short as possible and the project's performance is in good condition as well. Adopting C&P M, all tasks on the Critical Path execution time estimate is usually decreased by 25% to 50%, and this shortened time is assigned at the end of the project into a common safety buffer while the small tasks feeding buffers are at the end of each branch circuit at the points merging this chain part into the main Critical Chain. In this research, we took a 25% deduction from the important task.
3.3. Define Critical Chain Activity

Drawing the network diagram of critical path presented in Figure 3 below, there were 7 tasks within the path highlighted in red: destruction (B1), clean up (B2), wall-job (B3), ceilings and stairs (B5), painting job (B6), and waterproofing (B8). Referring to the data in Table III, the critical chain of this project is the activities of A4 (floor-job), A9 (painting), B3 (wall-job), B5 (ceilings and stairs), B6 (painting job), B8 (waterproofing) with a duration of 52 days. This Critical chain must be considered so that they will not experience any problems, because they can affect the completion duration of the entire project. The critical chain is shown in the following Figure 4.

![Critical Path Diagram](image1)

**Figure 3. Critical Path**

![Critical Chain Diagram](image2)

**Figure 4. Critical Chain**
Based on the data Fig. 3 and Fig. 4, the activities of B3, B5, B6, and B7 are the critical chain of this project with a duration of 28 days.

3.4. Using buffers in the project
Priority activities have the highest level of sensitivity to project delays, so it is necessary to protect these activities. Moreover, priority activities are activities including both in the critical path and critical chain. To protect these activities, it can be conducted by entering the project buffer at the end of the critical chain.

\[
Project\ buffer = \sum \text{duration (B3+B5+B6+B8)} \times 25\%
\]
\[
= 28 \text{ days} \times 25\%
\]
\[
= 7 \text{ days}
\]

3.5. Application of CCPM Calculation with Microsoft Project
The Microsoft Project software was employed for CCPM calculation. Both the traditional and CCPM produced a different result. The traditional schedule completed in 39 days of project time (Fig. 5), while the CCPM schedule showed 4 days faster including 7 days of project buffer (Fig. 6).

Thus, the CCPM calculation has a better completion time that the building renovation project can be accomplished in 35 working days, by preparing 7 days for the project buffer time.

4. Conclusion
Critical chain project management is one of a method to calculate and create schedule for project. By using critical chain management methods, it is found the critical chain namely B3, B5, B6, and B7. These activities are on factory building renovation projects, especially in the process of renovating factory facilities. At the end of the critical chain project, a project buffer of 7 days is added. This Project Buffer functions to control activities that are in the critical chain. A delay in activities in the critical chain can lead to a delay for all projects. Utilizing CCPM, the total project duration is 35 days. This
duration is 4 days ahead of the traditional scheduling calculation. For further research, it is necessary to calculate the cost of the change in the implementation schedule of this project, whether changing the schedule can increase the level of cost efficiency or increase the cost of the project, which indicates that the schedule change is not effective against the project cost.

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