Scheduling evaluation in construction projects using the critical chain project management method

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Abstract. PT. A is a company engaged in construction, EPC (Engineering, Procurement and Construction), infrastructure investment, property and real estate. The case study that was raised in this study was the construction project of the retaining wall and the ABC dock that was carried out by PT. A. The problem in the project is that the project scheduling is not good, causing delays in project completion. The purpose of this research is to evaluate the scheduling of the project so that the optimum schedule can be obtained in project implementation. The method used in this study is Critical Chain Project Management (CCPM). CCPM is a project scheduling method that can optimize the schedule due to the absence of multitasking. The CCPM begins by estimating the time without safeguarding the existing time on each job by using the Cut & Paste Method. The critical path serves to find out the critical or non-critical work or activity. Critical activities on wall construction projects anchoring land and ABC dock namely work keep directors. Based on buffer consumption monitoring indicators due to the potential for the emergence of waste will end in use of project buffer duration consumed during the 19-35 period day and immediately take action if the buffer is consumed in the period of 36-53 days. Based on evaluation with critical application Project chain management obtained one feeding 4-day buffer and duration of the buffer project 53 days with the existing scheduling period 432 days to 379 days without buffer consumption.

1. Introduction
Project is a business activity that is complex, irregular, limited by time, budget, resources and performance designed for consumer needs. Project implementation is generally a set of mechanisms for each task and activity each has a relationship in the end contains its own conflicts in it [1-3].

The delays on the delivery of construction projects are seen as one of the most frequent problems in the construction industry when activities require common resources that are available only in limited quantities [4,5]. Obstacles that constraints influence usually referred as triangles consisting of constrain projects from the scope of work, time and costs. Activities for planning, organizing, direct and control resources and organization to achieve certain goals within limited time and resources are a form of handling that we can define as project management [6,7].

The period of project activity starts at certain time and end according to the time of completion work on a project that is the background behind many projects that work delegated to outside people or institutions [8,9]. It has been shown that both the schedule risk analysis and project control should go hand in hand as useful tools to measure the project performance of a project in progress and to improve
the project control process and the corrective action decision making process in case the project is in danger [10].

The case study discussed in this study is the project construction of the retaining wall and ABC dock. Problem delay or length of work schedule involves many factors and obstacles that come well from the project owner and the project recipient (contract), regardless of the problem in the execution of the project does require careful planning, coordination and supervision because it involves various kinds of activities as well output. Therefore research was conducted with Critical Chain Project Management (CCPM) method to optimize feeding buffers and project buffers (extra time).

2. Method

2.1. Type of research
The type of research conducted is research case, that is research about an object that regard to a specific phase of the whole personality. Case research studies intensive background with the aim of giving detailed description of the background of case.

2.2. Research object
The object of research observed was scheduling projects run by PT. A. The choice of the object of this research is due to the background planning mismatch with schedule reality construction of the construction project that caused delay in the Soil Retaining Wall project and ABC Pier.

2.3. Research variable
Research variables are divided into two, namely independent variable and dependent variable. Variable independent is a variable that affects dependent variable both positively and negatively, while the dependent variable is a variable whose value or value is influenced or determined by other variable values. The independent variables in this study, namely: Time, the period needed in a work, Costs, costs required for implementation project, Resources, workers' needs, tools and materials on project implementation, and Method, Procedure for scheduling [11,12].

2.4. Conceptual framework
The conceptual framework is the shape of the framework thinking that is used as an inner approach to solve the problem. Conceptual framework generally described in a diagram. The conceptual framework in this study can be seen in Figure 1.

![Figure 1. Conceptual framework.](image-url)
2.5. Research data
Secondary data in this study consisted of data obtained in the finished form, company records or information from reports companies like company history, structure organization, cost budget plan (RAB) and s-curve. Data collection methods used in this study is the interview method. The results of this interview are in the most criteria affect failure in implementation construction.

3. Results and discussion

3.1. Estimated safeguard time results
In estimating the duration of the project must be based on the experience of the planner, where most scheduling planners tend to add the duration of the security hidden into their judgments for any uncertainty on actual performance [13,14]. Determination of predecessor as a link between activities. In determining the predecessor at the CCPM method of work non-urgent (non-critical) separated by the application of as late as possible as to avoid he existence of multitasking work [15,16].

Table 1. Some Recapitulation of Identification of Critical Paths

| Activity Code | Duration | Predecessor | Type of Linkage | ES | EF | LS | LF | TF |
|---------------|----------|-------------|-----------------|----|----|----|----|----|
| 4             | 49       |              |                 | 0  | 49 | 0  | 49 | 0  |
| 5             | 15       | 4           | FS + 25         | 74 | 89 | 49 | 64 | 0  |
| 47            | 6        | 45          | FS              | 331| 337| 331| 337| 0  |
| 52            | 12       | 51          | FS – 4          | 367| 379| 367| 379| 0  |

3.2. Management buffer result

3.2.1. Root square error method. This method uses two parameters time which is the standard time assumed as a time that still saves backup time (S) and the fastest time (A) that is assumed without backup time. Large buffer can be calculated using equations.

\[ 2\sigma = \sqrt{(S_1 - A_1)^2 + (S_2 - A_2)^2 + \ldots + (S_n - A_n)^2} \]  

(1)

Project buffers are used to protect the final project completion time from uncertainty schedule in critical chain activities. Project buffer placed at the end of the project after work which is in the last critical network. The following is the calculation of the size of the project buffer. The calculation of Project Buffer show in Table 2.

Table 2. Calculation results project buffer.

| Activity Code | S   | A   | S - A | S - A / 2 | (S - A)^2 / 2 |
|---------------|-----|-----|-------|-----------|---------------|
| 4             | 61  | 49  | 12    | 6         | 36            |
| 5             | 18  | 15  | 3     | 1.5       | 2.25          |
| 6             | 21  | 17  | 4     | 2         | 4             |
| 14            | 252 | 202 | 50    | 25        | 625           |
| Etc.          |     |     |       |           |               |
| Total         |     |     |       |           | 687.25        |

The project buffer is placed at the end of the track critical. Feeding buffers are used to protect and maintain the performance of critical chain network activities from changes due to uncertainty in the schedule inside activity from non-critical networks. Following is the calculation of Feeding Buffers in Table 3.
### Table 3. Calculation results of feeding buffer.

| Activity Code | $S$ | $A$ | $S - A$ | $\frac{S - A}{2}$ | $\left(\frac{S - A}{2}\right)^2$ |
|---------------|-----|-----|---------|-------------------|----------------------------------|
| 7             | 19  | 16  | 3       | 1,5               | 2,25                             |
| 8             | 7   | 6   | 1       | 0,5               | 0,25                             |
| Total         |     |     |         | 2,50              |                                  |

Based on the calculation of the buffer obtained:

- The project completion time is 379 working days without buffer consumption.
- Project completion time is 432 working days with the addition of the project buffer duration of 53 working days.

### 3.3. Results of estimated time labour costs buffer

The calculation of the project buffer is obtained the number of buffers is 53 working days and Feeding buffer 4 working days. Estimating the cost of time buffer to determine savings labour costs if the buffer time is at all not used. Estimated labour costs work per day at the time the buffer is calculated based on the assumption of average labour costs all work per day obtained from the RAB. Following is the average recapitulation labour costs for each job in Table 4.

### Table 4. Results some recapitulation of the average cost of each work.

| No. | Job Description | Duration (Days) |
|-----|-----------------|-----------------|
| 1.1 | Preparatory Work|                 |
| 1.1.2 | Temporary Project Facilities | | |
| 1.1.2.1 | The Board of Directors includes its facilities | 61 |
| 1.1.2.2 | Warehouse of materials and equipment | 18 |
| 1.1.2.3 | Worker barracks / beds | 17 |
| 1.2 | Work of Retaining Walls | |
| 1.2.1 | Procurement of Concrete Pile Sheet Type W600 B 1000, L = 20 m | 49 |
| Etc. | .... | .... |

### 3.4. Waste identification results

Identification of Waste (Concept 8 Waste and Root Cause Analysis) identify eight waste criteria contained in a project. Waste identification is processed using Root Cause Analysis (RCA) method. Based on the results actual interview job with the coordinator site operation field. The descriptions of root cause analysis activities shown in Table 5.

### Table 5. Root cause analysis.

| Waste | Sub Waste | Why | Why | Why | Why |
|-------|-----------|-----|-----|-----|-----|
| Defect | Poor Quality of Work | Weather Does Not Support Job Implementation |
| Material Quality Is Not Standard | There Are Mistakes Of Shipping From The Supplier |
| Not Thorough In Material Sorting | Not Implementing SOPs Correctly |
| Not Implementing SOPs Correctly | Lack of supervision |
| Waiting | Waiting for Material | Incorrect Delivery Schedule |
| Late Delivery From Suppliers | Lack of Coordination of Parties Concerned |
| Improper Planning |
| Etc. | ... | ... | ... | ... | ... |
3.5. Results of identification of buffer consumption zone

Identification due to potential emergence of waste will lead to use of project buffer duration which is designed as a safe working time project. This event really isn't expected because this can be done directly enlarge the cost of the project through duration increase. For this purpose a tool is needed scheduling controls that are able to involve uncertainty factor. Where on the CCPM method, the tool is a buffer indicator zone functions to monitor buffer consumption. Here's the description zone indicator based on Table 6.

| Consumption Zone Indicator | Project Buffer (Days) | Duration Used | Explanation                  |
|-----------------------------|----------------------|---------------|------------------------------|
| 0%–33%                      | 53                   | 0-18          | no action must be taken      |
| 34%–66%                     | 53                   | 19-35         | plan preventative actions    |
| 67%–100%                    | 53                   | 36-53         | set action                   |

The buffer will determine when the party project implementers take action based on mapping the amount of buffer time consumed. Party implementers need to control to take action related to the use of project buffer duration.

4. Conclusions

Conclusions that can be concluded in this article is as follows.

- Critical activities on wall construction projects anchoring land and ABC dock namely work keep directors including facilities, warehouse and materials equipment, barracks, bedding worker, steel pile 711 t = 14m, expansion joint, steel concrete foundation, steel, mechanical and electrical concrete.
- Based on buffer consumption monitoring indicators due to the potential for the emergence of waste will end in use of project buffer duration. Implementing party must do a preventive action plan if the buffer is consumed during the 19-35 period day and immediately take action if the buffer is consumed in the period of 36-53 days and making the root of the problem due to the potential for the emergence of waste as a consideration in determining preventive measures against buffer consumption.
- Based on evaluation with critical application Project chain management obtained one feeding 4-day buffer and duration of the buffer project 53 days with the existing scheduling period 432 days to 379 days without buffer consumption.

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