Application Of CPM Methode (Critical Path Methode) In Controlling the Time 100 Teus Conatrainer Ship Hull Construction Project

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Abstract
Construction projects are generally the most high-risk businesses, especially shipbuilding projects. Efforts to reduce the risk can be done by minimizing the potential risk. This study aims to see potential high risk and prevent delays in the completion of ship construction using the Critical Path Method CPM at PT. XYZ. By using the Critical Path Method CPM critical paths can be given more attention so that they will not interfere ship construction projects. In addition, it is also a form of anticipation if there is a delay, it is possible to reschedule.

Keywords: CPM Methode, Critical Path, Shipbuilding
1. Introduction

Construction projects are generally the most high-risk businesses [1]. The ship construction project is a competitive project with major risks such as the delay in delivery of the vessel to the owner, work accidents, and production errors that cause the ship not to match the owner's order so with a large level of risk need good planning and control in the field. Based on the Research Report on Shipbuilding Japan Cho et al (1996) it is known that the hull construction process is 48-50% of the shipbuilding process [2]. Delay is defined as the time overrun either beyond the contract's date or beyond the delivery date agreed upon by the project's different parties. PT. XYZ is a ship construction company collaborates with Damen Shipyard Gorinchem for the construction of new ships. In its planning, PT XYZ plans to build a 100 TEUs container ship on time and well managed. Using critical path analysis in ship construction scheduling planning is one of the most effective and efficient methods to prevent delays in ship construction completion.

1.1 Ship Construction

The stages of the hull construction itself are divided into several stages of work. The construction of the ship's hull can be divided into 4 stages [9], namely:

1. Fabrication Part: The fabrication is the earliest level of physical work when building a new ship. The fabrication section consists of several main activities, such as: marking, cutting, roll, press, bending
2. Sub-assembly Part: Sub-assembly process consists of fit-up and welding of production parts that have been carried out at the fabrication stage. Sub assembly process is combining several small components into components per panel.
3. Block assembly Part: Block assembly stage is one of core work on ship construction. Block assembly is the activity combining two or more panels to form a ship block. This merging process usually requires heavy equipment to support its production activities. This stage consists of 4 main activities, namely: JIG preparation, scantling check, fit-up, inspection.

1.2 Critical Path Method

Critical Path Method (CPM) is a technique for analyzing projects by determining the longest sequence of tasks (or the sequence of task with the least slack) through a project network [5]. The function of the critical path is to find out activities that have a very high sensitivity to delays in completing work, or also called critical activities [9]. By concentrating on the most critical tasks it can be ensured that the project is on time and is keeping pace with the schedule set up [3]. The project network is a flow chart that graphically depicts the sequence, inter dependence of the project work plan. One of the functions of the project network is to analyze activities that are on a critical path.

1.3 Project Management

A project is a complex undertaking, non-routine, one-time activity constrained by time, budget, resources, and performance specifications designed to meet customer requirements. The purpose of project management is that these activities can be achieved efficiently and effectively. In general, the project cycle and process from start to finish are as follows:

1. Defining
2. Planning
3. Executing
4. Closure

1.4 Term in Project Networking

Some of the terms often used in project networking are:

• ESij (early start), is earliest start time on activity (i,j) [4]. ES for each element (i,j) is equal with Ei for previous element.
  \[ S_{ij} = E_i \]  

• EF (early finish), is how fast an activity can be completed. EF for each element (i,j) is equal with ES plus duration of event.
  \[ E_{Fij} = E_{Sij} + D_{ij} \]  

• LF (late finish), is how late the activity can be completed. At each node we calculate the least finish and start energy for each activity by considering. Lj as the maximum/ latest occurrence
of node j [6]. LF for each element \((i,j)\) is equal with LET from previous j.

\[
LF_{ij} = L_j
\]  
(3)

- LS (late start), is how late an activity can be started. LS for each element \((i,j)\) is equal with LF minus duration of event.

\[
LS_{ij} = LF_{ij} - D_{ij}
\]  
(4)

- Slack / Float, is how long the activity is delayed. Activity i is regarded as a critical activity if its float time is zero [7].

1.5 Arranging of Critical Path Network
1. List project / process activities
2. Draw a diagram
3. Calculate & analyze the earliest event time (EET)
4. Calculate & analyze the latest event time (LET)
5. Determine the critical path

2. Methods
The type of study is case study research. Case study research, through reports of past studies, allows the exploration and understanding of complex issues. It can be considered a robust research method particularly when a holistic, in-depth investigation is required.

The data needed in this study will be taken from production data construction of new hull construction. The primary data needed are: data on the intensity of the occurrence of each type of waste. Data collection the weight of the intensity of the waste is carried out by using a questionnaire method on several respondents in companies that have experience in their fields. Primary data the other is the respondent's data on the priority risk rating for the company.

The data will be processed to see the potential for high risk and prevent delays in the completion of ship construction using the Critical Path Method CPM.

3. Results and Discussion
3.1 Data Collection
Data collection was carried out at PT. XYZ with the object of research on the construction of a 100 TEUS container ship.

In the picture above, it can be seen that PT. XYZ builds 100 TEUS container ships with 33 blocks ship assembly part.
### TABLE 1. DURATION OF EACH PROCESS

| No | Activity               | Code | Dependency Logic | Duration (days) |
|----|------------------------|------|------------------|-----------------|
| 1  | Block Fabrication 1    | A1   | Starting         | 5               |
| 2  | Block Fabrication 2    | A2   | A1               | 5               |
| 3  | Block Assembly 1       | B1   | A1               | 26              |
| 4  | Block Assembly 2       | B2   | A2               | 30              |
| 5  | Block Fabrication 3    | A3   | A2               | 5               |
| 6  | Block Assembly 3       | B3   | A3               | 28              |
| 7  | Block Fabrication 4    | A4   | A3               | 5               |
| 8  | Block Assembly 5       | B4   | A4               | 25              |
| 9  | Block Fabrication 7    | A5   | A4               | 5               |
| 10 | Block Assembly 8       | B5   | A5               | 25              |
| 11 | Block Fabrication 4    | A6   | A5               | 8               |
| 12 | Block Assembly 9       | B6   | A6               | 25              |
| 13 | Block Fabrication 6    | A7   | A6               | 5               |
| 14 | Block Assembly 10      | B7   | A7               | 29              |
| 15 | Block Fabrication 10   | A8   | A7               | 5               |
| 16 | Block Assembly 10      | B8   | A8               | 32              |
| 17 | Erection Block 1-2-3   | C1   | B1, B2, B3      | 40              |
| 18 | Block Fabrication 10   | A9   | A8               | 5               |
| 19 | Block Assembly 11      | B9   | A9               | 42              |
| 20 | Block Fabrication 17   | A10  | A9               | 5               |
| 21 | Block Assembly 21      | B10  | A10              | 45              |
| 22 | Block Fabrication 14   | A11  | A10              | 5               |
| 23 | Block Assembly 14      | B11  | A11              | 30              |
| 24 | Block Fabrication 18   | A12  | A11              | 5               |
| 25 | Block Assembly 18      | B12  | A12              | 46              |
| 26 | Block Fabrication 13   | A13  | A12              | 5               |
| 27 | Block Assembly 13      | B13  | A13              | 45              |
| 28 | Block Fabrication 8    | A14  | A13              | 5               |
| 29 | Block Assembly 8       | B14  | A14              | 29              |
| 30 | Block Fabrication 12   | A15  | A14              | 5               |
| 31 | Block Assembly 12      | B15  | A15              | 31              |
| 32 | Block Fabrication 15   | A16  | A15              | 5               |
| 33 | Block Assembly 15      | B16  | A16              | 50              |
| 34 | Block Fabrication 16   | A17  | A16              | 5               |
| 35 | Block Assembly 16      | B17  | A17              | 50              |
| 36 | Block Fabrication 14   | A18  | A17              | 5               |
| 37 | Block Assembly 14      | B18  | A18              | 40              |
| 38 | Erection Block 5-7     | C2   | B4, B5           | 46              |
| 39 | Block Fabrication 19   | A19  | A18              | 5               |
| 40 | Block Assembly 19      | B19  | A19              | 55              |
| 41 | Block Fabrication 20   | A20  | A19              | 5               |
| 42 | Block Assembly 20      | B20  | A20              | 53              |
| 43 | Erection Block 9-17    | C3   | B9, B10          | 43              |
| 44 | Block Fabrication 21   | A21  | A20              | 5               |
| 45 | Block Assembly 21      | B21  | A21              | 58              |
| 46 | Erection Block 9-10    | C4   | C1, B8, B9      | 25              |
| 47 | Block Fabrication 22   | A22  | A21              | 5               |
| 48 | Block Assembly 22      | B22  | A22              | 52              |
| 49 | Block Fabrication 23   | A23  | A22              | 5               |
| 50 | Block Assembly 23      | B23  | A23              | 60              |
| 51 | Block Fabrication 24   | A24  | A23              | 5               |
| 52 | Block Assembly 24      | B24  | A24              | 49              |
| 53 | Block Fabrication 25   | A25  | A24              | 5               |
| 54 | Block Assembly 25      | B25  | A25              | 66              |
| 55 | Block Fabrication 26   | A26  | A25              | 5               |
| 56 | Block Assembly 26      | B26  | A26              | 70              |
| 57 | Block Fabrication 27   | A27  | A26              | 5               |
| 58 | Block Assembly 27      | B27  | A27              | 57              |
| 59 | Erection Block 4-6     | C5   | C1, B6, B7      | 32              |
| 60 | Block Fabrication 28   | A28  | A27              | 5               |
| 61 | Block Assembly 28      | B28  | A28              | 67              |
| 62 | Block Fabrication 29   | A29  | A28              | 5               |
| 63 | Block Assembly 29      | B29  | A29              | 65              |
| 64 | Erection Block 11-18   | C6   | B11, B12, C3    | 56              |
| 65 | Block Fabrication 30   | A30  | A29              | 5               |
| 66 | Block Assembly 30      | B30  | A30              | 72              |
Basically, this critical chain calculation aims to determine the critical activities in the overall project activity. The way to determine critical activities in critical chain analysis is to calculate the float time available for activities. Float time is waiting time for an activity before moving on to the next activity. The float time calculation is according to the formula in sub-chapter 2. In the construction of a 100 TEUS container ship, the critical activities for each of the entire project series are described in table below.

| Activity Code | Dependency Logic | Duration (days) | Time (Days) | Information |
|---------------|------------------|-----------------|-------------|-------------|
|               |                  |                 | EST | EFT | LST | LFT | Float |            |
| A1            | Start            | 5               | 0   | 5   | 0   | 5   | 0   | Critical   |
| A2            | A1               | 5               | 5   | 10  | 5   | 10  | 0   | Critical   |
| B1            | A1               | 26              | 5   | 31  | 457 | 483 | 452 |           |
| B2            | A2               | 30              | 10  | 40  | 455 | 483 | 443 |           |
| A3            | A2               | 5               | 10  | 15  | 10  | 15  | 0   | Critical   |
| B3            | A3               | 28              | 15  | 43  | 455 | 483 | 440 |           |
| A4            | A3               | 5               | 15  | 20  | 15  | 20  | 0   | Critical   |
| B4            | A4               | 25              | 20  | 45  | 434 | 459 | 414 |           |
| A5            | A4               | 25              | 25  | 50  | 434 | 459 | 409 |           |
| B5            | A5               | 8               | 25  | 33  | 25  | 33  | 0   | Critical   |
| A6            | A6               | 25              | 33  | 58  | 498 | 523 | 465 |           |
| B6            | A6               | 5               | 33  | 38  | 33  | 38  | 0   | Critical   |
| A7            | A7               | 29              | 38  | 67  | 494 | 523 | 456 |           |
| B7            | A7               | 5               | 38  | 43  | 38  | 43  | 0   | Critical   |
| A8            | A8               | 32              | 43  | 75  | 498 | 530 | 455 |           |
| B8            | A8               | 40              | 43  | 83  | 483 | 523 | 440 |           |
| C1            | B1, B2, B3       | 40              | 43  | 83  | 483 | 523 | 440 |           |
| A9            | A9               | 42              | 48  | 90  | 432 | 474 | 384 |           |
| B9            | A9               | 42              | 48  | 90  | 432 | 474 | 384 |           |
| A10           | A10              | 5               | 48  | 53  | 48  | 53  | 0   | Critical   |
| B10           | A10              | 45              | 53  | 96  | 429 | 474 | 376 |           |
| A11           | A10              | 5               | 53  | 58  | 53  | 58  | 0   | Critical   |
| B11           | A11              | 30              | 58  | 88  | 469 | 499 | 411 |           |
| A12           | A11              | 5               | 58  | 63  | 58  | 63  | 0   | Critical   |
| B12           | A12              | 46              | 63  | 109 | 453 | 499 | 390 |           |
| A13           | A12              | 5               | 63  | 68  | 63  | 68  | 0   | Critical   |
| B13           | A13              | 45              | 68  | 113 | 460 | 505 | 392 |           |
| A14           | A13              | 5               | 68  | 73  | 68  | 73  | 0   | Critical   |
| B14           | A14              | 29              | 73  | 102 | 476 | 505 | 403 |           |
| A15           | A14              | 5               | 73  | 78  | 73  | 78  | 0   | Critical   |
| B15           | A15              | 31              | 78  | 109 | 524 | 555 | 446 |           |
| A16           | A15              | 5               | 78  | 83  | 83  | 83  | 0   | Critical   |
| B16           | A16              | 50              | 83  | 133 | 505 | 555 | 422 |           |

TABLE 2. CRITICAL ACTIVITY

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21 | Jurnal Akuntansi, Ekonomi dan Manajemen Bisnis | Vol. 9 No.1, July 2021, 17-24 | E-ISSN: 2548-9836
In the table above, it can be seen that critical activities are activities that do not have waiting time for the next activity. So that critical activities are activity with zero float value. In addition, the critical path can also be seen from the project network diagram shown in fig 3 below.
Then an analysis of the causes of delays in the project schedule is carried out, especially in the scope of critical activities. Based on the critical activity chain analysis, the activities that have a zero float value are:

1. Fabrication: A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23
2. Assembly: B23
3. Erection: C9, C10, C12, C13, C18, C19

4. Conclusion

From the results of research and discussions that have been carried out, several conclusions are obtained as follows:

1. By using the Critical Path Method CPM in scheduling, it is known that the age for a 100 TEUS ship construction project from start to finish is 555 days
2. Critical Path for a 100 TEUS ship construction project is an activity with the notation A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, B23, C9, C10, C12, C13, C18, C19.

Suggestions from the results of research and discussion, it can be suggested to the contractor to:

1. Activities/works that are on a critical path can be given more attention because they can disrupt the overall 100 TEUS ship construction project.
2. If there is a delay in returning, the contractor can reschedule with methods of accelerating projects that are on the critical path.

However, this research was conducted at the planning stage of shipbuilding. So the analysis of this critical path method can be a risk prevention of time delays in shipbuilding projects. In addition, the analysis from this research can be used by company as a reference in contractual agreements with ship owners.

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