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Hospital Auxiliary Vessel Fore Part Zone Planning to Improve Productivity with *Precedence Diagram* Method

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***Abstract*— The rapid development of Construction Management in Indonesia demands an efficient scheduling system to overcome project complexity. This study focuses on the process of building a hospital ship at one of the large shipyards in East Java, especially in the *Fore Part Zone* which has a high level of complexity and a limited number of blocks. Delays in this project are caused by several technical constraints such as machine breakdowns and drawing delays. This research aims to improve productivity by using the *Precedence Diagram Method* (PDM), which enables more optimal work scheduling by overcoming overlapping activities. Three scheduling scenarios were compared: Existing, Plan A, and Plan B. Plan A involved *crashing* techniques with the addition of overtime hours to accelerate critical Assembly activities (A13 and A14), resulting in a project duration of 301 days and productivity of 74.80 JO/day. Plan B integrated the drawing availability milestone as a prerequisite for the start of fabrication, and applied the same *crashing* as Plan A. As a result, Plan B was able to complete the project in 284 days with the same productivity, but with a more realistic and adaptive scheduling approach to field conditions. Based on critical path analysis and time efficiency, Plan B is the most optimal schedule for the construction of Fore Part Zone. This research is expected to be a reference in planning and controlling complex ship construction projects.**

Keywords— *Construction Management, PDM, Productivity, Fore Part Zone, Hospital Ship.*

I. INTRODUCTION

Rapid developments in construction management in Indonesia encourage the need for good and effective project scheduling, calculations must be carried out carefully, planned and thoroughly in order to minimize the risk of delays, while optimizing project time and cost efficiency.

One of the large shipyards in East Java has received many ship orders from within and outside the country, but has limited facilities and resources. One of the orders is a hospital ship whose construction is divided into six zones.

The Fore Part zone is the focus of the study because it only consists of 14 blocks (the least) but has the highest duration in implementation. This was due to delays in the working drawings and breakdowns of some production equipment such as shot blasting machines and overhead cranes. In addition, the fore part zone has a complex curvature (especially on the bulbous bow) that requires high precision in fabrication and installation.

Various scheduling methods such as Critical Path Method (CPM), Bar Chart, S Curve and Precedence Diagram Method (PDM) have been used in project planning.

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CPM is an important technique used to identify the critical path that determines the total duration of the project. This method helps project managers prioritize crucial tasks, manage resources efficiently, and anticipate delays. CPM is very effectively used on large-scale and complex projects to ensure timely completion [1]

Bar Chart is a visual representation that displays a list of activities vertically and time horizontally, with the length of the bar indicating the duration of the activity [2]. This method is popular in project planning because it looks simple, easy to understand, and makes it easy to monitor the schedule and progress of work efficiently

An S curve is a graph that shows cumulative project progress by time and percentage of work weight or cost. By comparing the planned and actual S Curves, project managers can evaluate whether the project is running on schedule, late, or ahead of schedule [3]

Precedence Diagram Method (PDM) is a project planning method that emphasizes financial efficiency and management of project completion time. This method organizes the relationship between project activities to accelerate completion without reducing quality. PDM also helps optimize the use of resources, especially manpower, to make project implementation more effective. By understanding the dependencies between activities, project managers can create a schedule that is realistic and adaptive to change. According to [4], PDM is an important tool for balancing the use of labor, time, and cost. One of the commonly used applications to implement this method is Microsoft Project.

From the analysis, PDM shows a much higher level of efficiency due to its ability to organize activities that can overlap. This means that the next activity can be started before its predecessor is fully completed, as long as the dependency between activities is maintained. With this flexibility, project completion time can be significantly optimized [2].

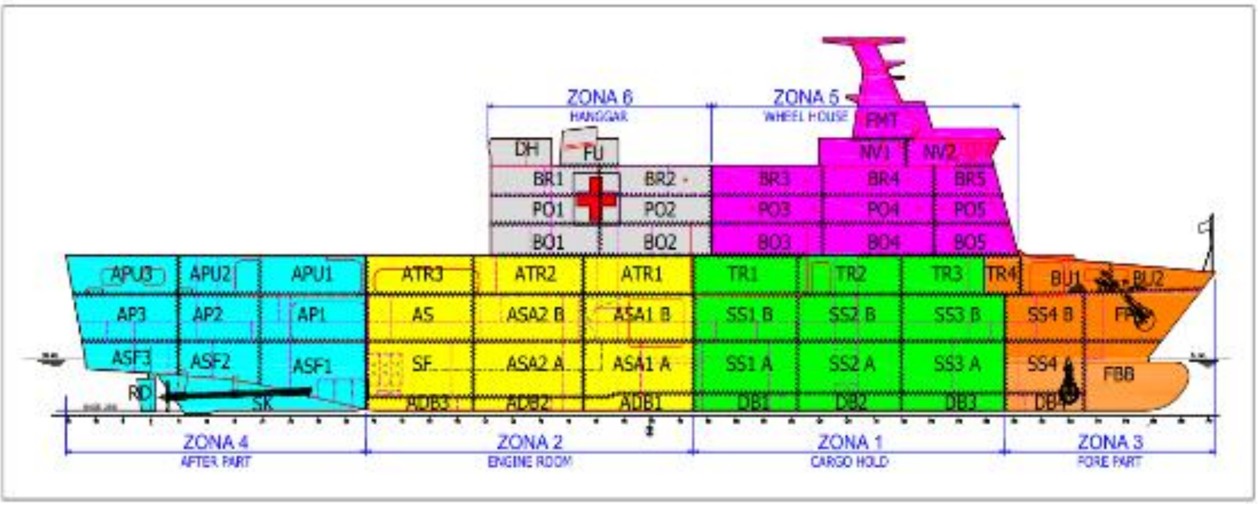

Figure 1. Zones of shipbuilding

In previous research, the application of PDM is generally used in the context of construction projects in general or shipping projects that do not focus on specific zones (such as research by Romadhona 2021, Virginia 2022, Amani 2012). In addition to focusing on the Fore Part Zone, this research also identifies the critical trajectory of the project, and evaluates productivity through the calculation of man hours (JO), as well as implements crashing for schedule acceleration by taking into account cost impacts. Therefore, this research provides a new contribution in scheduling optimization and resource efficiency in the shipyard industry.

II. METHOD

A. Definition of Project Management

Project management is the process of integrating tools, resources, and techniques to achieve specific goals, including planning, organization, implementation, and control [5]. Each stage in a project can be affected by various factors that impact the overall project lifecycle. Schedule delays are generally caused by scope changes, poor procurement, shortage of skilled labor, weak planning, inexperienced contractors, and low subcontractor performance. Therefore, project scheduling, budgeting, and control become very important [6].

B. PDM Theory

Precedence Diagram Method (PDM) is an efficient and structured project scheduling technique, similar to the Activity-On-Node (AON) method, and emphasizes the balance between project cost and duration (Michelle Andriana, 2022). PDM relies on four basic relationships:

1. Finish-to-Start (FS) - the next activity starts after the previous activity is completed.
2. Start-to-Start (SS) - two activities start simultaneously even though their durations differ.
3. Finish-to-Finish (FF) - two activities finish together even though they started differently.
4. Start-to-Finish (SF) - a rare relationship, the opposite of FS.

Important terms in PDM include:

1. ES/EF: earliest start and finish times.
2. LS/LF: the latest start and finish times without interrupting the project.
3. D (Duration**)**: activity completion time.

[7]

4. Total Float: the time an activity can be delayed without delaying the project (TF = LF - EF or LS - ES) [8].
5. Crashing Project: accelerating the project by adding minimum cost through network analysis [9].

C. Microsoft Project

In construction work, applications such as Microsoft Project are very helpful in creating work schedules in the field and overcoming potential delays [4]. Microsoft Project is a project management software that supports efficient and systematic project planning, tracking, resource allocation, and analysis [10].

Some important terms in Microsoft Project:

1. Task: Details of the work in the project.
2. Duration: Length of time.
3. Start/Finish: The start and finish dates of the work.
4. Predecessor: Relationship between jobs.
5. Resources: Human/material resources.
6. Cost: Labor and material costs.
7. Baseline: The project's reference plan.
8. Tracking: Monitoring project progress.
9. Milestone: Marks the completion of a stage of work (duration = 0).
10. Outlining: Grouping of work.
11. Lag Time (+) and Lead Time **(-)**: Pause or overlap between jobs.
12. Critical Task: Important work that cannot be late.

13. Total Slack: Maximum delay time without disrupting the project.

Type of relationship between jobs:

1. Finish to Start (FS): Work starts after the previous work is completed.
2. Finish to Finish (FF): Two jobs are completed simultaneously.
3. Start to Start (SS): Two jobs are started simultaneously.
4. Start to Finish (SF): A job is completed after another job is started [11]

D. People Hours

Man-hour is a unit used to measure the extent to which the progress of a job is achieved, especially in large projects such as ship construction and repair. Man hours are calculated by multiplying the total number of workers by the duration of working time per person in hours [12]. So it can be formulated as follows:

JO =

where :

JO = Person Hours
MP = Man Power
JE = Effective Hours per day (hour)
D = Duration (days)

In the shipping industry, shipyards determine man-hour requirements based on factors such as work experience, task load, work standards, project duration, and other relevant parameters. Accurate man-hour data is an important basis for resource planning, project control, and progress evaluation, and supports the smooth and efficient execution of work [12].

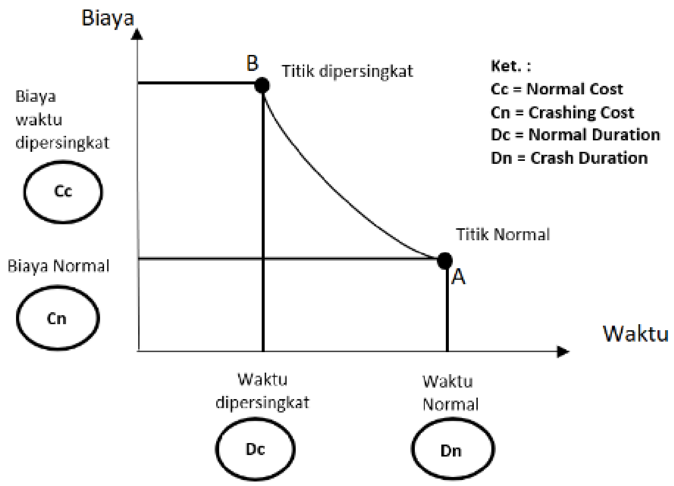

Figure. 1. Time and cost relationship chart

E. Productivity

Productivity is the ratio between output and labor contribution in a certain time, an indicator of the efficiency and success of the industry or shipyard. The level of productivity is influenced by the optimization of the factors of production, namely:

1. Man (labor)
2. Machine (machine/technology)
3. Materials (raw materials)
4. Money (capital)
5. Method
6. Markets

Labor is a key factor, where efficiency, skills, and good management are crucial to successful production and productivity. [13]

F. Fore Part Zone

According to [14], blocks that have been welded can be assembled and combined with other blocks to form the overall ship structure. This joining process is known as zone oriented, where each block or part of the ship is arranged according to a certain zone or area in the ship design. Fore Part zones are groupings of blocks at the front of the ship. This approach simplifies management, increases efficiency, speeds up the assembly process, and reduces the risk of construction errors.

This research uses quantitative methods to describe the project conditions in a measurable manner. The analysis was conducted by applying PDM using actual data from the Hospital ship block production process. This approach aims to identify and optimize the work schedule, so as to obtain a clear and accurate picture of project efficiency.

G. Flowchart of research

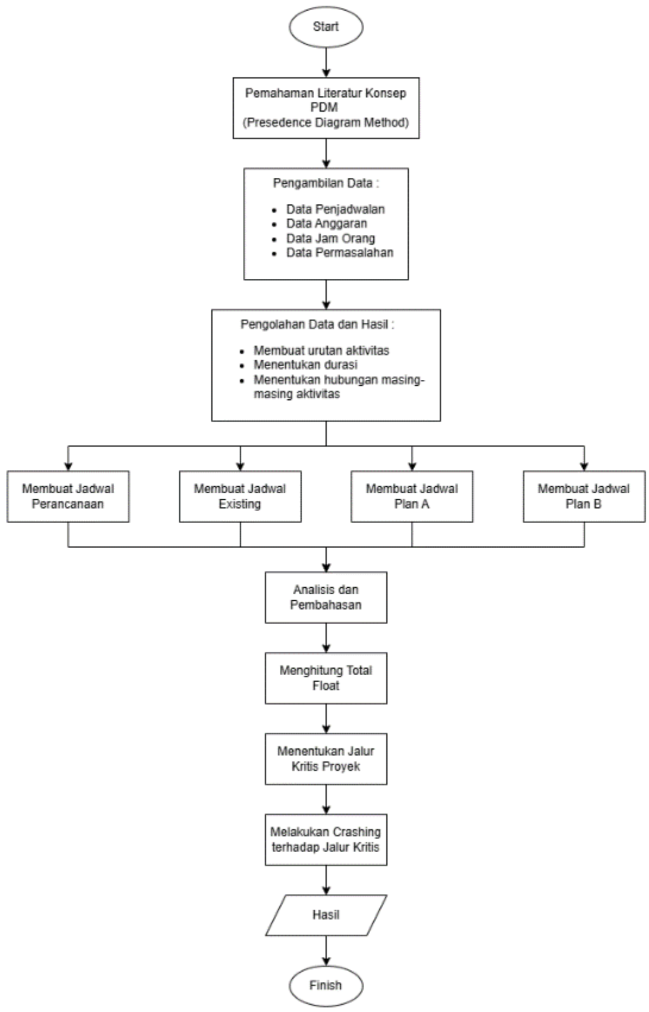

Figure 3. Research Flowchart

H. Research Stages

1. Collection of Project data:
   a. Project schedule, budget, resources used.
   b. Identification of data causing delays in the block production stage
2. Data processing using PDM:
   a. Create a sequence of activities
   b. Determining duration
   c. Determine the relationship between each activity
   d. Create a schedule using PDM
3. Data analysis:
   a. Perform forward counting
      ➔ EF = ES + duration
   b. Performing a countdown
      ➔ LS = LF- duration

   c. Calculate Total Float with one of two formulas
      ➔ Total Float = LF - EF or
      Total Float = LS - ES
   d. Determine the critical path of the project (Total Float = 0)
   e. *Crashing* the critical path.
4. Evaluation and Interpretation of Results:
   a. Identify and determine the critical trajectory at the *Fore Part zone* block production stage.
   b. Knowing the impact generated in analyzing scheduling using the PDM method.
   c. Identify corrective measures that can be taken to control costs and time in the future, particularly on similar projects.

III. RESULTS AND DISCUSSION

In this study, project data were obtained, namely time schedule data and Fore Part Zone man hours at the planning and existing stages consisting of activities, duration of block construction from Fabrication to Assembly and relationships between blocks which were then analyzed into new scheduling using PDM. The time schedule data will be presented in the form of tables, PDM schedules and Microsoft Project (MP) schedules.

A. Planning Stage
   1. Activity relationship

TABLE 1.
RELATIONSHIP BETWEEN PLANNING STAGE ACTIVITIES

Task Name	Code	Relationship	Duration (days)
Fabrication	F		
Fab. Block DB 4	F1		18
Fab. Block SS 4A P	F2	F1SS+11	18
Fab. Block SS 4A S	F3	F1SS+11	18
Fab. Block SS 4B P	F4	F2SS+14	18
Fab. Block SS 4B S	F5	F3SS+14	18
Fab. Block TR 4 P	F6	F4SS+15	17
Fab. Block TR 4 S	F7	F5SS+15	17
Fab. Block FBB	F8	F6FS+67, F7FS+67	14
Fab. Block FP P	F9	F8SS+9	15
Fab. Block FP S	F10	F8SS+9	15
Fab. Block BU 1 P	F11	F9SS+10	14
Fab. Block BU 1 S	F12	F10SS+10	14
Fab. Block BU 2 P	F13	F11SS+12	14
Fab. Block BU 2 S	F14	F12SS+12	14
Assembly	A		
Ass. Block DB 4	A1	F1SS+4	38
Ass. Block SS 4A P	A2	F2SS+3, A1SS+3	48
Ass. Block SS 4A S	A3	F3SS+5, A2SS+2	47
Ass. Block SS 4B P	A4	F4SS+4, A3SS+12	48
Ass. Block SS 4B S	A5	F5SS+5, A4SS	48
Ass. Block TR 4 P	A6	F6SS+3, A5SS+12	48
Ass. Block TR 4 S	A7	F7SS+4, A6SS+1	48
Ass. Block FBB	A8	F8FS+7	48
Ass. Block FP P	A9	F9FS+5, A8SS+9	48
Ass. Block FP S	A10	F10FS+5, A9SS+2	48
Ass. Block BU 1 P	A11	F11FS+9, A10SS+10	48
Ass. Block BU 1 S	A12	F12FS+10, A11SS+2	48
Ass. Block BU 2 P	A13	F13FS+9, A12SS+10	48
Ass. Block BU 2 S	A14	F14FS+10, A13SS+2	48

2. PDM Schedule

The PDM schedule in Figure 3.1 is made based on the planning stage activity relationship. After forward counting and backward counting, the total float value of each activity is obtained. The total float value = 0 illustrates that the activity is on the critical path. Activities that are on the critical path are marked with red code. According to Figure 3.1 the activities on the critical path in the Fabrication process (F) are F1, F2, F3, F4, F5, while in the Assembly process are A6, A7, A11, A12, A13 and A14. And planned to be completed on day 228.

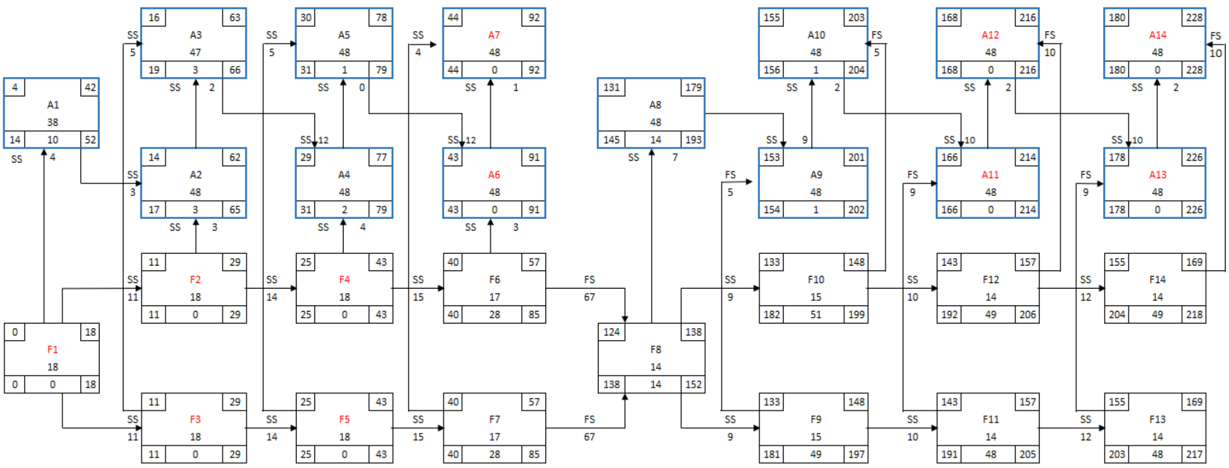

Figure 4. Planning stage PDM schedule

3. People Hours Plan

Its productivity can be calculated as follows:

F = JOF: DF

= 2.228 : 169

= 13.18 JO/day

PA = JOA: DA

= 14.787 : (228-4)

= 14.787 : 224

= 66.01 JO/day

While

PT = (JOF+JOA) ; DT

= (2.228+14.787) : 228

=17.015 : 228

=74.62 JO/day

Where → PF: Fabrication Productivity
PA: Assembly Productivity
PT: Total Productivity
JOF: Hour People Fabrication
JOA: Jam People Assembly
DF: Fabrication Duration
DA: Assembly Duration
DT: Total Duration

The productivity of the Fabrication process is 13.18 JO, the Assembly process is 66.01 JO and the total productivity per day is 74.62 JO.

TABLE 2.
PEOPLE HOURS PLAN

NO	BLOCK	PEOPLE HOURS FABRICATION (F)	ASSEMBLY (A)
1	DB 4	97	568
2	SS 4A P	198	1160
3	SS 4A S	161	946
4	FBB	349	2832
5	SS 4B P	207	1207
6	SS 4B S	205	1202
7	FP P	332	2505
8	FP S	233	1767
9	TR 4 P	180	1050
10	TR 4 S	150	878
11	BU 1 P	15	86
12	BU 1 S	15	86
13	BU 2 P	43	250
14	BU 2 S	43	250
	TOTAL	2.228	14.787

B. Existing Stage

1. Existing Stage Activity Relationship

TABLE 3.
ACTIVITY RELATIONSHIP OF EXISTING STAGE

Task Name	Code	Relationship	Duration (days)
Fabrication	F		
Fab. Block DB 4	F1		38
Fab. Block SS 4A P	F2	F1FS+9	20
Fab. Block SS 4A S	F3	F1FS+9	20
Fab. Block SS 4B P	F4	F9SS+84	15
Fab. Block SS 4B S	F5	F10SS+84, F4SS	15
Fab. Block TR 4 P	F6	F4SS+72	15
Fab. Block TR 4 S	F7	F5SS+72	15
Fab. Block FBB	F8	F1SS+33	136
Fab. Block FP P	F9	F2SS+14	14
Fab. Block FP S	F10	F3SS+14, F9SS	14
Fab. Block BU 1 P	F11	F6SS+15	24
Fab. Block BU 1 S	F12	F7SS15, F11SS	24
Fab. Block BU 2 P	F13	F11SS+5	19
Fab. Block BU 2 S	F14	F12SS+5, F13SS	19
Assembly	A		
Ass. Block DB 4	A1	F1SS+12	33
Ass. Block SS 4A P	A2	F2SS+12, A8SS+5	23
Ass. Block SS 4A S	A3	F3SS+14, A2SS+2	21
Ass. Block SS 4B P	A4	F4SS+10, A10SS+88	28
Ass. Block SS 4B S	A5	F5SS+16, A4SS+6	28
Ass. Block TR 4 P	A6	F6SS+18, A5SS+74	45
Ass. Block TR 4 S	A7	F7SS+18, A6SS	45
Ass. Block FBB	A8	F8SS+20	121
Ass. Block FP P	A9	F9SS+5, A3SS+5	50
Ass. Block FP S	A10	F10SS+6, A9SS+1	61
Ass. Block BU 1 P	A11	F11SS+3, A7SS+1	13
Ass. Block BU 1 S	A12	F12SS+4, A11SS+1	13
Ass. Block BU 2 P	A13	F13SS+4, A12SS+4	59
Ass. Block BU 2 S	A14	F14SS+4, A13SS	59

2. Existing stage PDM schedule

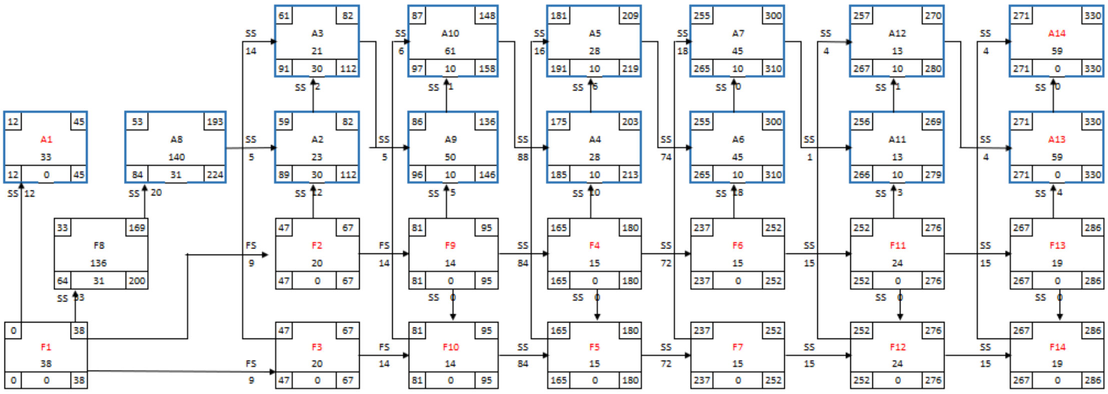

Figure 5. PDM Schedule of Existing stage

The existing stage PDM schedule in Figure 3.2 has a schedule shift due to differences in the relationship / sequence of work and duration of some activities when compared to the planning. The critical trajectory of the existing stage in the Fabrication process (F) is in F1 to F14 except F8, and in the Assembly process (A) is in A1, A13 and A14. Completion of block construction for 330 days

3. Existing People Hours

From table 3.4, the existing productivity can be calculated as follows:

PF = JOF: DF
= 5.151 : 286
= 18.01 JO/day

PA = JOA: DA
= 17.126 : (330-12)
= 17.126 : 318
= 53.85 JO/day

While

PT = (JOF+JOA) : DT
= (5.151+17.126) : 330
= 22.277 : 330
= 67.51 JO/day

The productivity per day of the existing stage of the Fabrication process is 18.01 JO, Assembly process 53.85 JO and Total productivity 67.51 JO. The block completion duration is 330 days. The delay in block completion can be calculated as follows:

DT = DE - DP
= 330 - 228
= 102 days

Where ➔ DT: Late Duration
DE: Existing Duration
DP: Planning Duration

C. Plan A Schedule

From the existing data, it is found that the delay in the construction of the Fore Part Zone block is 102 days from the planned schedule. The biggest delay is in activities A13 and A14, which is from 48 days to 59 days. Because the schedule of activities F13 and F14 shifted 112 days (267 - 155) and the duration of A13 and A14 increased, activities A13 and A14 became the longest activity. To minimize delays, crashing is done by adding overtime hours.

Existing man-hours for activity A13 is 234 JO with a duration of 59 days while activity A14 is 239 JO with a duration of 59 days as well. If overtime hours of 4 hours per day are added, the following calculation is obtained:

Activity A13

Total JO (TJOE) = 234 JOs
Duration (D) = 59 days
Working hours (JN) = TJOE/D
= 234 / 59
= 3.96➔ rounded up 4 Hours

Overtime (JL) = 4 hours per day
Total working hours (JNL = JN + JL = 4 + 4 = 8 Hours
Duration of completion (DS) = TJOE : JNL
= 234 : 8
= 29.25➔ rounded up to 30 days

Activity A14

Total JO (TJOE) = 239 JOs
Duration (D) = 59 days
Working hours (JN) = TJOE / D = 239 / 59
= 4.05➔ rounded up 4 Hours

Overtime (JL) = 4 hours per day
Total working hours (JNL) = JN + JL = 4 + 4 = 8 Hours
Duration of completion (DS) = TJOE : JNL
= 239 : 8
= 29.87➔ rounded up to 30 days

With a JO Rate of Rp. 52,800, the additional cost required is:
Cost Addition = JL x DS x JO Rate x 2
= 4 x 30 x 52,800 x 2

= 12.672.000

From both activities A13 and A14, if overtime hours are added 4 hours per day, the completion duration is 30 days and the additional cost required is Rp. 12,672,000, -

TABLE 2.
EXISTING PEOPLE HOURS

		PEOPLE HOURS	
NO	BLOCK	FABRICATION (F)	ASSEMBLY (A)
1	DB 4	84	397
2	SS 4A P	597	1285
3	SS 4A S	474	1054
4	FBB	888	3655
5	SS 4B P	527	1827
6	SS 4B S	451	713
7	FP P	618	2454
8	FP S	439	1743
9	TR 4 P	314	1534
10	TR 4 S	254	1183
11	BU 1 P	165	301
12	BU 1 S	131	507
13	BU 2 P	109	234
14	BU 2 S	100	239
	TOTAL	5.151	17.126

4. Activity relationship schedule Plan A

TABLE 3.
ACTIVITY RELATIONSHIP OF PLAN A

Task Name	Code	Relationship	Duration (days)
Fabrication	F		
Fab. Block DB 4	F1		38
Fab. Block SS 4A P	F2	F1FS+9	20
Fab. Block SS 4A S	F3	F1FS+9	20
Fab. Block SS 4B P	F4	F9SS+84	15
Fab. Block SS 4B S	F5	F10SS+84, F4SS	15
Fab. Block TR 4 P	F6	F4SS+72	15
Fab. Block TR 4 S	F7	F5SS+72	15
Fab. Block FBB	F8	F1SS+33	136
Fab. Block FP P	F9	F2SS+14	14
Fab. Block FP S	F10	F3SS+14, F9SS	14
Fab. Block BU 1 P	F11	F6SS+15	24
Fab. Block BU 1 S	F12	F7SS15, F11SS	24
Fab. Block BU 2 P	F13	F11SS+5	19
Fab. Block BU 2 S	F14	F12SS+5, F13SS	19
Assembly	A		
Ass. Block DB 4	A1	F1SS+12	33
Ass. Block SS 4A P	A2	F2SS+12, A8SS+5	23
Ass. Block SS 4A S	A3	F3SS+14, A2SS+2	21
Ass. Block SS 4B P	A4	F4SS+10, A10SS+88	28
Ass. Block SS 4B S	A5	F5SS+16, A4SS+6	28
Ass. Block TR 4 P	A6	F6SS+18, A5SS+74	45
Ass. Block TR 4 S	A7	F7SS+18, A6SS	45
Ass. Block FBB	A8	F8SS+20	121
Ass. Block FP P	A9	F9SS+5, A3SS+5	50
Ass. Block FP S	A10	F10SS+6, A9SS+1	61
Ass. Block BU 1 P	A11	F11SS+3, A7SS+1	13
Ass. Block BU 1 S	A12	F12SS+4, A11SS+1	13
Ass. Block BU 2 P	A13	F13SS+4, A12SS+4	30
Ass. Block BU 2 S	A14	F14SS+4, A13SS	30

2. PDM Plan A Schedule

PDM Plan A schedule in Figure 3.3 the activity relationship is the same as the existing schedule but for the duration of the Assembly process (A) activities A13 and A14 have been crashing additional overtime hours of 4 hours per day so that the duration becomes 30 days. The critical path on the PDM plan A schedule is also the same as the critical path at the existing stage. While the completion of block construction for 301 days

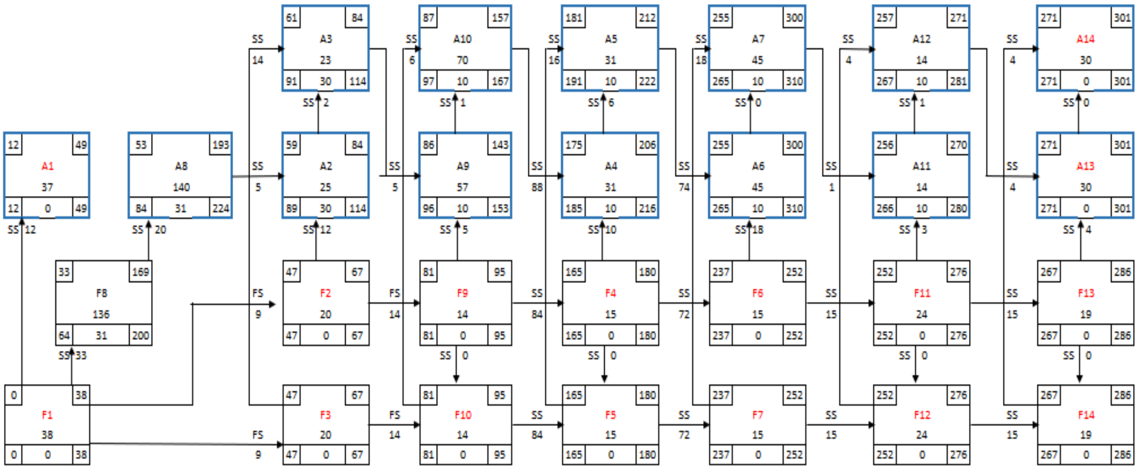

Figure. 6. PDM Schedule Plan A

3. People Hours Plan A

From table 3.6 the Productivity of the Fabrication process is the same as the Existing Schedule while the Productivity of the Plan A Assembly block process can be calculated as follows:

PA = JOA : DA
= 17.366 : (301-12)
= 17.366 : 289
= 60.09 JO/day

While

PT = (JOF+JOA) ; DT
= (5.151+17.366) : 301
= 22.517 : 301
= 74.80 JO/day

So that the productivity per day of the Plan A schedule for the Fabrication process is 18.01 JO, the Assembly process is 60.09 JO and the total productivity per day is 74.80 JO.

TABLE 4.
PLAN A PEOPLE HOURS

NO	BLOCK	PEOPLE HOURS FABRICATION (F)	PEOPLE HOURS ASSEMBLY (A)
1	DB 4	84	397
2	SS 4A P	597	1285
3	SS 4A S	474	1054
4	FBB	888	3655
5	SS 4B P	527	1827
6	SS 4B S	451	713
7	FP P	618	2454
8	FP S	439	1743
9	TR 4 P	314	1534
10	TR 4 S	254	1183
11	BU 1 P	165	301
12	BU 1 S	131	507
13	BU 2 P	109	354
14	BU 2 S	100	359
TOTAL		5.151	17.366

D. Plan B Schedule

It has been stated that damage to several facilities, material delays and delays in drawing availability are some of the things that cause delays in block construction. However, the delay in drawing availability is the most significant cause so that in Plan B scheduling, drawing availability information data will be used as a milestone in scheduling. In the PDM Plan B schedule, the G code is information from the availability of drawings. If the drawing is available, the new Fabrication (F) activity can be started, followed by the next activity until completion.

In addition to the image information, the plan B schedule is also crashing as in the Plan A Schedule so that the duration for the Assembly process (A) activities A13 and A14 is still 30 days.

In the PDM Plan B schedule, all activities in the Fabrication and Assembly processes are on the critical path. The total duration of block construction can be completed on day 284.

1. Plan B schedule activity relationship

TABLE5.
PLAN B ACTIVITY RELATIONSHIP

Task Name	Code	Relationship	Duration (days)
Image	G		
Fig. Block DB 4	G1		0
Fig. Block SS 4A P/S	G2/G3	G8FS+15	0
Fig. Block SS 4B P/S	G4/G5	G9/G10+86	0
Image. Block TR 4 P/S	G6/G7	G11/G12FS+3	0
Fig. Block FBB	G8	G1FS+37	0
Fig. Block FP P/S	G9/G10	G2/G3FS+11	0
Fig. Block BU 1 P/S	G11/G12	G4/G5FS+68	0
Fig. Block BU 2 P/S	G13/G14	G6/G7+19	0
Fabrication	F		
Fab. Block DB 4	F1	G1FS+1	38
Fab. Block SS 4A P	F2	F3SS	20
Fab. Block SS 4A S	F3	G2/G3FS+1	20
Fab. Block SS 4B P	F4	F5SS	15
Fab. Block SS 4B S	F5	G4/G5FS+1	15
Fab. Block TR 4 P	F6	F7SS	15
Fab. Block TR 4 S	F7	G6/G7FS+1	15
Fab. Block FBB	F8	G8FS+1	136
Fab. Block FP P	F9	F10SS	14
Fab. Block FP S	F10	G9/G10FS+1	14
Fab. Block BU 1 P	F11	F12SS	24
Fab. Block BU 1 S	F12	G11/G12FS+1	24
Fab. Block BU 2 P	F13	F14SS	19
Fab. Block BU 2 S	F14	G13/G14FS+1	19
Assembly	A		
Ass. Block DB 4	A1	F1SS+12	33
Ass. Block SS 4A P	A2	F2SS+12	23
Ass. Block SS 4A S	A3	F3SS+14	21
Ass. Block SS 4B P	A4	F4SS+10	28
Ass. Block SS 4B S	A5	F5SS+16	28
Ass. Block TR 4 P	A6	F6SS+18	45
Ass. Block TR 4 S	A7	F7SS+18	45
Ass. Block FBB	A8	F8SS+20	121
Ass. Block FP P	A9	F9SS+5	50
Ass. Block FP S	A10	F10SS+6	61
Ass. Block BU 1 P	A11	F11SS+3	13
Ass. Block BU 1 S	A12	F12SS+4	13
Ass. Block BU 2 P	A13	F13SS+4	30
Ass. Block BU 2 S	A14	F14SS+4	30

2. PDM Plan B Schedule

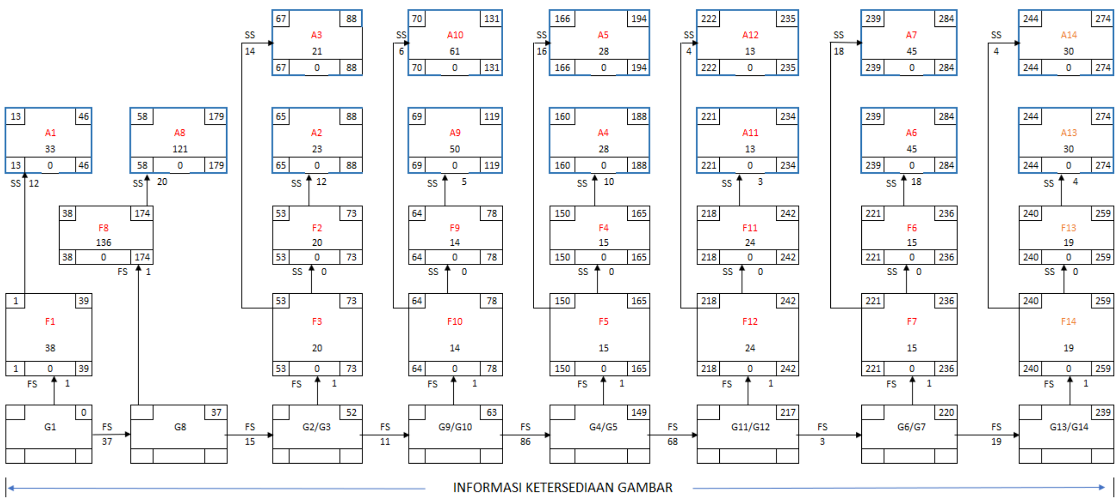

Figure 7. PDM Plan B Schedule

Assuming the person hours of Schedule Plan B are the same as the person hours of Schedule Plan A (according to table 3.6) then the Productivity of Schedule Plan B is :

PF = JOF: DF

= 5.151 : 259

= 19.88 JO/day

PA = JOA: DA

= 17.366 : (284-13)

= 17.366 : 271
= 64.08 JO/day

While

PT = (JOF+JOA) : DT
= (5.151+17.366) : 284
= 22.532 : 284
= 79.33 JO/day

The daily productivity of Plan B schedule for Fabrication process is 19.88 JO, Assembly process is 64.08 JO and total productivity is 79.33 JO.

Based on the results of the comparative analysis of various schedules, it can be summarized for man-hours, duration and total productivity as follows:

1. Schedule Plan
   People Hours : 17,015 JO
   Duration : 228 days
   Productivity : 74.62 JO/day
2. Existing Schedule
   People Hours : 22,277 JO
   Duration : 330 days
   Productivity : 67.51 JO/day
3. Plan A Schedule
   People Hours : 22,517 JO
   Duration : 301 days
   Productivity : 74.8 JO/day
4. Plan B Schedule
   People Hours : 22,532 JO
   Duration : 284 days
   Productivity : 79.33 JO/day

From the resume can be outlined:

1. The Existing schedule has the lowest productivity (67.5 JO/day), which means the work is slower than other options.
2. The Plan A schedule (74.8 JO/day) is still within reasonable limits**,** as it is slightly higher than Plan (74.6 JO/day).
3. The Plan B schedule has the highest productivity (79.33 JO/day), meaning that in one day, labor works more than other schedules.

To determine the most optimal schedule, it is necessary to look at the balance between duration, productivity and number of man-hours. Shorter duration means faster completion of the block construction, realistic productivity so that the workforce can work efficiently without overwork. The optimal number of workers so as not to burden the cost too much.

Higher productivity means work gets done faster. But effectiveness is not only about productivity, but also the duration and total person-hours used. Higher productivity is not always more effective because if it is forced, it will lead to several risks including overwork, fatigue that reduces the quality of work, additional costs such as more shifts or overtime and not according[1] to capacity, for example, the workforce is not able to maintain its rhythm so that repeated mistakes occur.

Comparative Analysis

1. Duration
   a. Plan B is shorter than Plan A (284 and 301 days, respectively), meaning faster completion.
   b. Plan A is longer than Plan, but more balanced in its productivity.
2. Productivity
   a. Plan B has the highest productivity (79.33 Jo/day) so it is faster to complete, but can be high risk for labor.
   b. Plan A is closer to Plan in that the productivity (74.8 Jo/day and 74.62 Jo/day) is more reasonable, but the duration is longer.
3. Labor Efficiency
   a. Plan A and Plan B increase people hours, but for different durations:
   b. Plan B is completed faster than Plan A with the same number of man-hours.
   c. This means that Plan B is more efficient than Plan A if labor is able to maintain its productivity.

To accelerate the completion of the construction of the Fore Part Zone block, Schedule Plan B is a more optimal schedule because Schedule Plan B has :

1. Shorter duration than Plan A (284 vs 301 days or 17 days faster than Plan A).
2. Productivity is higher (79.33 Jo/day), meaning work is completed faster.
3. The number of man-hours is the same as Plan A, but Plan B is more efficient in project completion.

The Plan B schedule is the most effective for shortening the duration without adding excessive person-hours.

IV. CONCLUSION

1. Based on the results of scheduling using the Precedence Diagram Method (PDM), the critical path in the construction of the Fore Part zone was identified. The critical path consists of activities with a total float equal to zero consisting of :
   a. The critical trajectory of the existing PDM schedule is the same as the critical trajectory in plan A, namely for the Fabrication process (F) in activities F1 to F14 except F8, and the Assembly process (A) in activities A1, A13 and A14.
   b. On the Plan B schedule, all activities in the Fabrication and Assembly processes are on the critical path.
2. After crashing the activities on the critical path, especially Assembly activities A13 and A14 on the PDM plan A schedule, the project duration efficiency is obtained. The duration of A13 and A14 which was originally 59 days on the Existing schedule became 30 days while the total duration of the project which was originally 330 days on the Existing schedule can be reduced to 301 days with additional costs that are still within reasonable limits, amounting to Rp12,672,000, -.

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