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Analysis of Reduction Cost of Assembly Block Side Shell 1A (SS 1A) Using Critical Path Method (CPM) in Hospital Ship Project

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Abstract
The hospital ship project is a major project that has a long period of time, with limited space allocation and human resources as well. In order to avoid problems for PT XXX related to project completion, namely experiencing delays, where many factors affect the course of the project, an improvement analysis is needed for optimization. Optimization is done by scheduling a new project with the hope that in the next similar project PT XXX will not experience similar problems. Using Critical Path Method (CPM) analysis, the assembly process of Block Side Sheel 1A (SS 1A) on the Hospital Ship Project has a work network analysis with acceleration on activities E-F-G-J-K-L-M-N-S, through analysis steps using overtime. Thus, it takes an acceleration cost of Rp. 6,943,510, or an additional cost of 32.26% of the initial cost to minimize the time from 64 days to 37 days, so that there is no delay in future hospital projects.

Keyword: Hospital Ship Project, Cost Reduction, Critical Path Method (CPM).

1. INTRODUCTION

PT XXX is a strategic defense industry that manufactures Indonesia's main defense equipment (Alutsista). The company operates in the fields of new shipbuilding, ship repair, and the manufacture of maritime support equipment [1]. In carrying out all of its projects, PT XXX uses Microsoft Project tools that focus on scheduling [3]. The implementation of planned project schedules is often inconsistent or delayed. This is due to several factors such as material delays, design revisions by the owner, discrepancies in NDT&UT test results, external factors, and so on [2]. As shown in Figure 1, PT XXX has undertaken twelve (12) shipbuilding projects over the past five years (2019-2023), with varying levels of project delays each year.

The company determines the time and costs required solely based on previous project experience. The company often faces issues with project completion timelines because the completion time does not align with the previously agreed-upon schedule. This is the background for this research [2]. The object of this study is the assembly activities on Block Side Shell 1A (SS 1A). This is because Block Side Shell 1A (SS 1A) is a block located in the main engine area, playing a crucial role in the main engine loading process on the ship and having a high level of urgency in the work process, particularly in the assembly process of Block Side Shell 1A (SS 1A). The hospital ship project is a multi-year or ongoing project, which will be continued in the following year in national and international projects [1].

2. METHOD

This chapter explains the research flow of Analysis of Reduction Cost of Assembly Block Side Shell 1A (SS 1A), starting from the problem identification process to drawing conclusions. Therefore, the author created a flowchart or research flowchart in Figure 1 below so that the research flow can be understood.

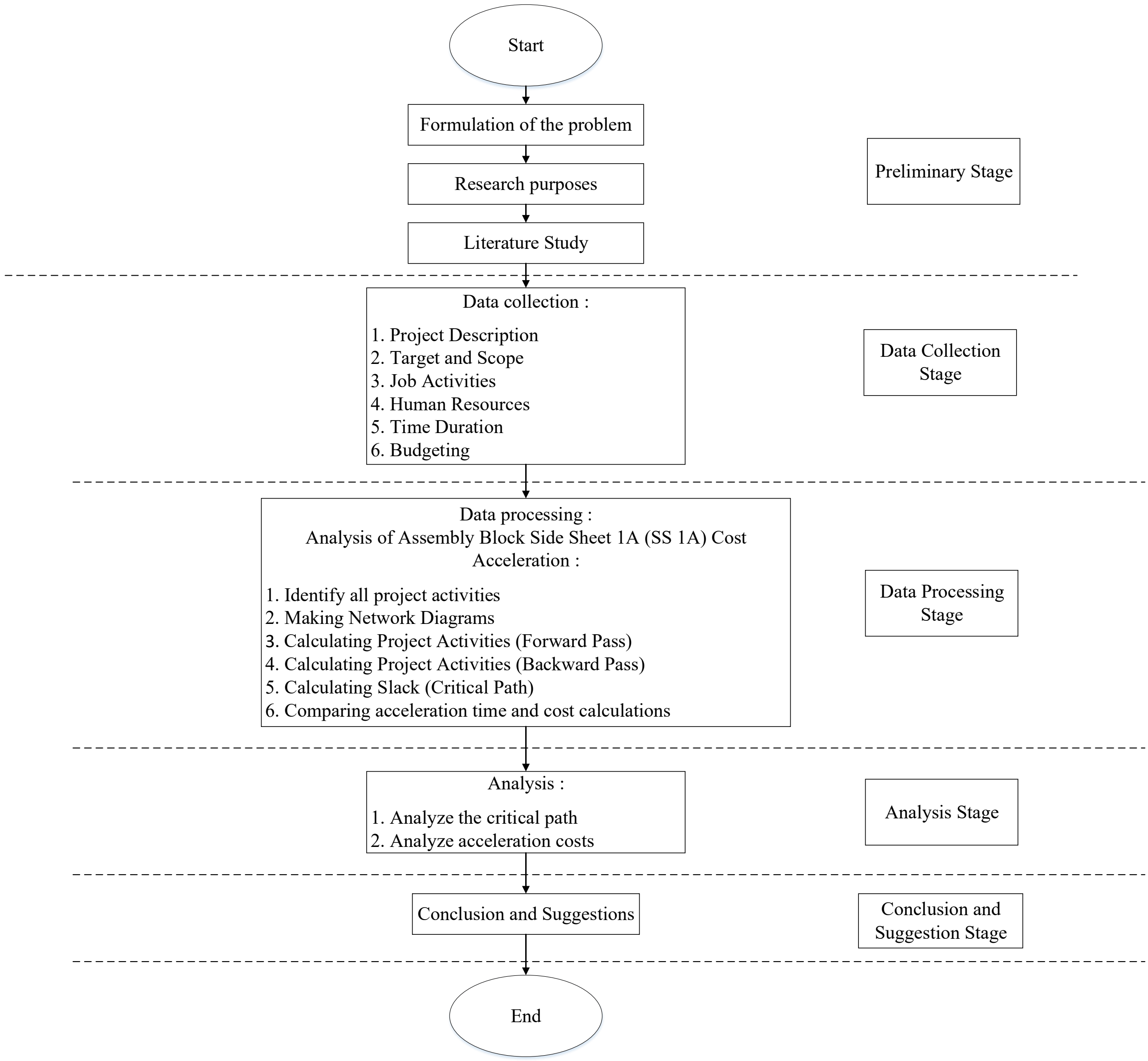

Figure 1. Research Flowchart

The following is an explanation of the flow diagram above:

- Identification and formulation of problems, determining the problems to be discussed in research after identifying them in the field.
- At the preliminary stage there are items formulation of the problem, research purpose, and literature study.
- Literature study, collecting and compiling a theoretical basis related to the research title.
- Data collection, research data collection stage such as scheduling data, person hours and problems in the production process.
- After the data has been collected, the next stage is processing the data according to its classification in the form of identifying all project activities, making network diagram, calculating project activities in forward pass and backward pass, calculating slack, comparing acceleration time and cost calculations.
- After the data processing analysis is correct, the next step is to draw conclusions from the research.

- Conclusion, the conclusion section will briefly explain the results of the research that has been carried out.

2.1 Research Object

The Hospital Ship Project is a project owned by the Indonesian Navy (TNI-AL), which was built and functions as a floating medical care facility or hospital and is part of the Republic of Indonesia Warship (KRI). The Hospital Ship has technical specifications of 124 meters long, 22 meters wide, and 6.8 meters high. The ship has a displacement of 7,300 tons, with a maximum speed of 18 knots, a cruising speed of 14 knots, and a minimum endurance of 30 days.

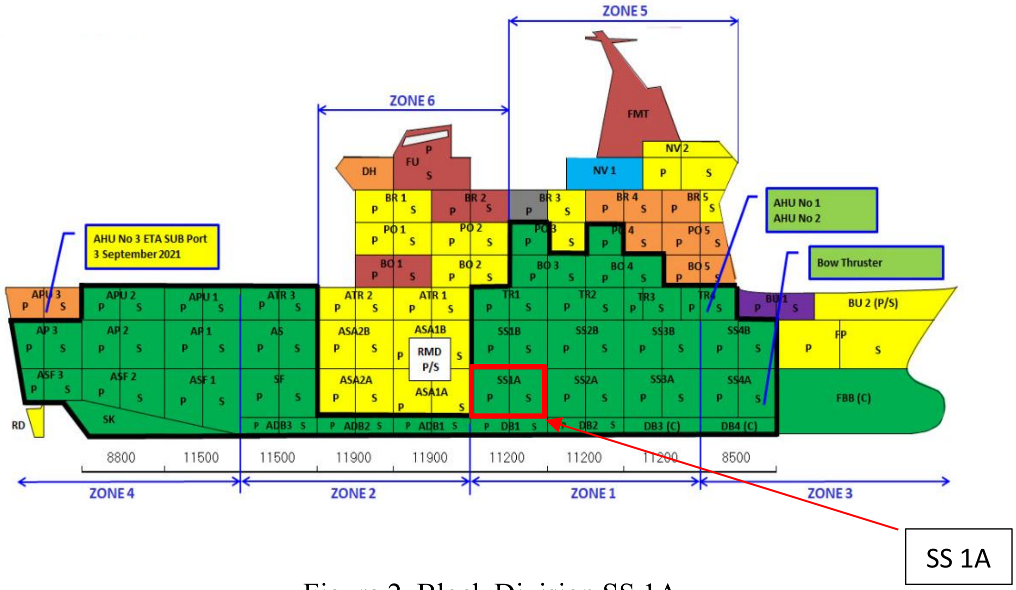

Figure 2. Block Division SS 1A

2.2 Project Network

According to [6], a project network is a network used to represent a project. A project network consists of a number of nodes displayed as small circles or rectangles and a number of arcs indicated by arrows leading from one node to another. The first type of network is an activity-on-arc (AOA) project network, where each activity is represented by an arc, and the second type is an activity-on-node (AON) project network, where each activity is represented by a node.

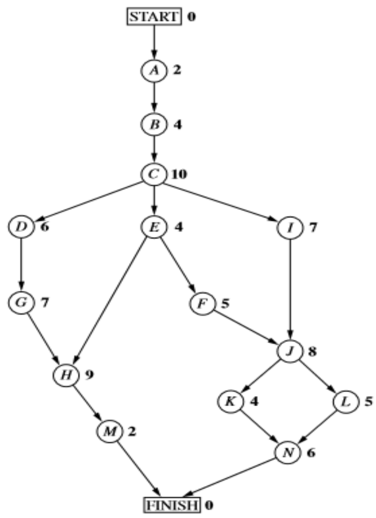

Figure 3. Project Network

The network in Figure 2 is an Activity-on-Node (AON) network, where each node, containing a letter representing the activity's initial, is assigned a number representing the duration of each activity.

The Concept of the Critical Path Method (CPM)

According to [11], one well-known method and technique for organizing the work components of a project scope into a work network, assigning time periods to each component, and analyzing the project completion time or schedule is the critical path method (CPM). Activity duration in the work network method is the length of time required to complete the activity from start to finish. The time period is generally expressed in hours, days, or weeks. The duration calculation in the CPM method is used to estimate activity completion time using a single duration estimate. The formula used to calculate activity duration is:

$$D = \frac{V}{Pr.N} \quad (1)$$

Note:
D = Activity duration
V = Activity volume
Pr = Average work productivity
N = Number of workers and equipment

The critical path and float are the sequence of activities that have the shortest completion time (ES) with several general conditions, namely:

- For the first activity: ES = LS = 0
- For the last or terminal activity: LF = EF.
- Total float: TF = 0.

2.3 Project Acceleration

According to [11], the primary goal of accelerating a project is to shorten the scheduled time while minimizing cost increases. To analyze the relationship between time and cost for an activity, the cost of shortening the time by one day can be calculated using the formula:

$$\text{Cost Slope} = \frac{\text{Shortened Cost} - \text{Normal Cost}}{\text{Normal Time} - \text{Shortened Time}} \quad (2)$$

3. RESULTS AND DISCUSSIONS

The main data that the author obtained from the field is scheduling data and working hours data. From this main data, the author obtained data in the form of master schedule data for planning and actual work in the SS 1A block, and working hours (JO) data. To calculate labor costs. The following are planning and actual data for the JO SS 1A block shown in Table 1 below using the CPM method.

Table 1. SS 1A Assembly Block Process Data Summary

No	Description	Activity	Predecessor	Time (Day)
1	Prepare Grand Assembly Loading & Adjusting Block SS 1A P/S	A	-	1
2	Grand Assembly Loading & Adjusting Grand Block SS 1A P	B	A	1
3	Grand Assembly Loading & Adjusting Grand Block SS 1A S	C	A	2
4	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A P	B1	B	1
5	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A S	C1	C	2
6	Grand Assembly Fitting Grand Block SS 1A S X Grand Block SS 1A P	D	B1, C1	3
7	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	D	8
8	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	E	2

No	Description	Activity	Predecessor	Time (Day)
9	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	F	2
10	Erection Loading & Adjusting Erection Block SS 1A P	H	G	1
11	Erection Loading & Adjusting Erection Block SS 1A S	I	H	1
12	Erection Fitting Erection Block SS 1A P X DB 1 P	J	I	3
13	Erection Fitting Erection Block SS 1A S X DB 1 S	K	J	3
14	Erection Welding Erection Block SS 1A P X DB 1 P	L	K	7
15	Erection Welding Erection Block SS 1A S X DB 1 S	M	J	7
16	RC Repair Fitting Erection Block SS 1A S	N	L	2
17	RC Repair Tutup Opening Lambung Opening Lambung Block SS 1A S	O	L	2
18	RC Repair Welding Erection Block SS 1A P	P	K	2
19	RC Repair Welding Erection Block SS 1A S	Q	M	2
20	RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R	N	2
21	Erection Vacuum Test Erection Block SS 1 A P	S	O	2
22	Erection Vacuum Test Erection Block SS 1 A S	T	P	2
23	Finishing RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R1	R	2
24	Finishing Erection Vacuum Test Erection Block SS 1 A P	S1	S	2
25	Finishing Erection Vacuum Test Erection Block SS 1 A S	T1	T	2

3.1 Acceleration and Cost

Project acceleration, implemented in project scheduling, aims to reduce the duration of critical tasks on the critical path, thereby shortening the activity completion schedule while minimizing costs using the critical path method (CPM).

Table 2. Forward Pass Calculation of SS 1A Block

No	Activity	Predecessor	Eeti	Duration (Day)	EETj
1	A	-	0	1	1
2	B	A	1	1	2
3	C	A	1	2	3
4	B1	B	2	1	3
5	C1	C	3	2	5
6	D	B1,C1	5	3	8
7	E	D	8	8	16
8	F	E	16	2	18
9	G	E	16	2	18
10	H	F	18	1	19
11	I	G	18	1	19
12	J	H	19	3	22
13	K	I	19	3	22
14	L	J	22	7	29
15	M	K	22	7	29
16	N	M	29	2	31
17	O	M	29	2	31
18	P	L	29	2	31
19	Q	N	31	2	33
20	R	O	31	2	33
21	S	P	31	2	33
22	T	Q	33	2	35
23	R1	R	33	2	35
24	S1	S	33	2	35
25	T1	T	35	2	37

Table 3. Backward Pass Calculation of SS 1A Block

No	Activity	Predecessor	Eeti	Duration (Day)	EETj
1	T1	T	37	2	35
2	S1	Q	35	2	33
3	R1	S	33	2	31
4	T	P	35	2	33
5	S	R	33	2	31
6	R	O	31	2	29
7	Q	N	33	2	31
8	P	L	33	2	31
9	O	M	31	2	29
10	N	M	31	2	29
11	M	K	31	7	24
12	L	J	29	7	22
13	K	I	22	3	19
14	J	H	22	3	19
15	I	G	19	1	18
16	H	F	19	1	18
17	G	E	18	2	16
18	F	E	18	2	16
19	E	D	16	8	8
20	D	B1,C1	8	3	5
21	C1	C	5	2	3
22	B1	A	3	2	1
23	C	B	3	1	2
24	B	A	2	1	1
25	A	-	1	1	0

The existing network, network model CPM method 1 critical path, and network model CPM method 2 critical Path of SS 1A assembly block process is shown in Figure 4 below.

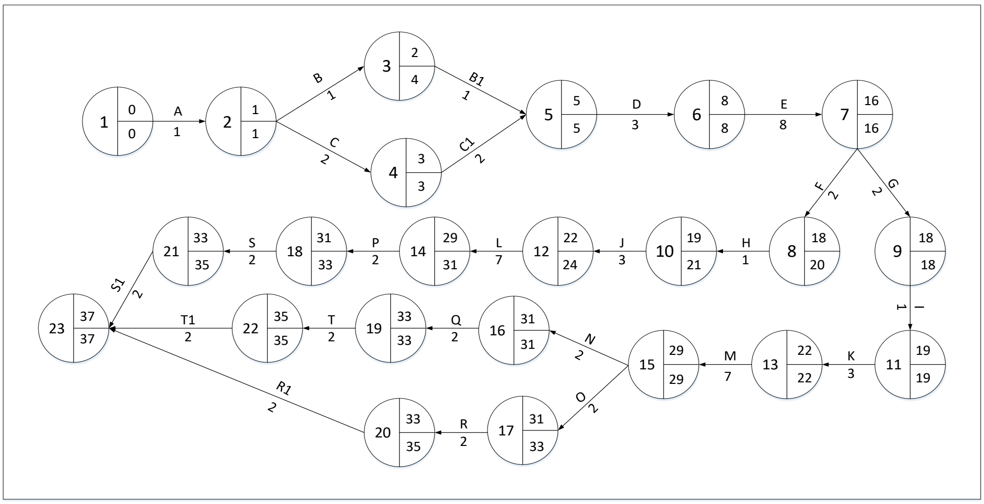

Figure 4. Existing Network Diagram

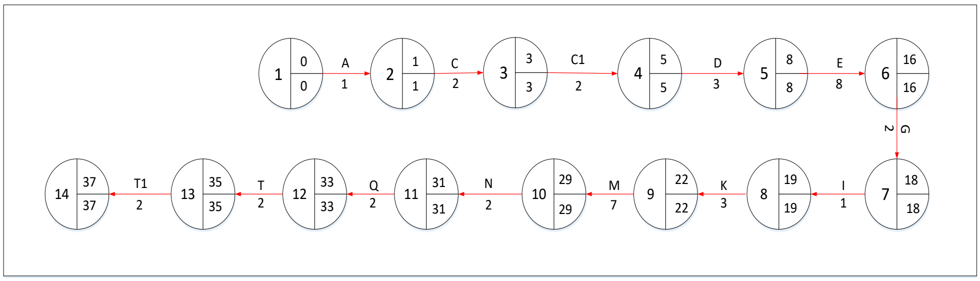

Figure 5. Network Diagram for CPM Method

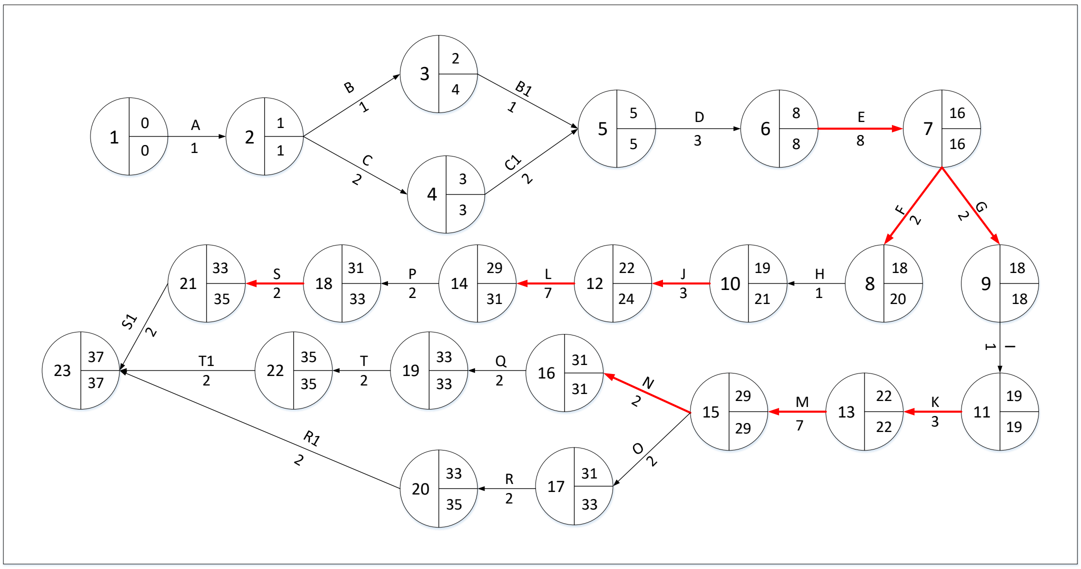

Figure 6. Network Diagram for CPM 2 Method

Acceleration analysis of the SS 1A assembly block process is shown in Table 4 below.

Table 4. Acceleration Analysis of the SS 1A Assembly Block Process

No	Description	Activity	Time (Day)	Acceleration Time (Day)	Optimal Duration (Day)	Jo-L	Jo-N	Total Jo
1	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	8	4	4	25,5	21,5	47,0
2	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	2	1	1	6,0	7,0	13,0
3	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	2	1	1	3,0	7,5	10,5
4	Erection Fitting Erection Block SS 1A P X DB 1 P	J	3	1	2	24,5	21,0	45,5
5	Erection Fitting Erection Block SS 1A S X DB 1 S	K	3	1	2	16,0	21,0	37,0
6	Erection Welding Erection Block SS 1A P X DB 1 P	L	7	3	4	19,5	20,0	39,5
7	Erection Welding Erection Block SS 1A S X DB 1 S	M	7	3	4	16,5	28,0	44,5
8	RC Repair Fitting Erection Block SS 1A S	N	2	1	1	3,0	37,5	40,5
9	Erection Vacuum Test Erection Block SS 1 A P	S	2	1	1	6,0	11,0	17,0

Based on the acceleration analysis of the Block SS 1A assembly process, through data processing using the Critical Path Method (CPM), efforts were made to increase overtime hours, as shown in the table. However, this was not applied to all activities, only to certain activities: E, F, G, J, K, L, M, N, and S. The costs required for the Block SS 1A assembly process are shown in tables below.

Table 5. Summary of Initial Costs in the SS 1A Assembly Block Process

No	Description	Activity	Total Jo	Early Cost (Rp)
1	Prepare Grand Assembly Loading & Adjusting Block SS 1A P/S	A	11,00	543.620,00
2	Grand Assembly Loading & Adjusting Grand Block SS 1A P	B	2,5	123.550,00

No	Description	Activity	Total Jo	Early Cost (Rp)
3	Grand Assembly Loading & Adjusting Grand Block SS 1A S	C	7,5	370.650,00
4	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A P	B1	2,5	123.550,00
5	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A S	C1	7,5	370.650,00
6	Grand Assembly Fitting Grand Block SS 1A S X Grand Block SS 1A P	D	29	1.433.180,00
7	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	47,0	2.322.740,00
8	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	13,0	642.460,00
9	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	10,5	518.910,00
10	Erection Loading & Adjusting Erection Block SS 1A P	H	22,0	1.087.240,00
11	Erection Loading & Adjusting Erection Block SS 1A S	I	22,5	1.111.950,00
12	Erection Fitting Erection Block SS 1A P X DB 1 P	J	45,5	2.248.610,00
13	Erection Fitting Erection Block SS 1A S X DB 1 S	K	37,0	1.828.540,00
14	Erection Welding Erection Block SS 1A P X DB 1 P	L	39,5	1.952.090,00
15	Erection Welding Erection Block SS 1A S X DB 1 S	M	44,5	2.199.190,00
16	RC Repair Fitting Erection Block SS 1A S	N	40,5	2.001.510,00
17	RC Repair Tutup Opening Lambung Opening Lambung Block SS 1A S	O	3,5	172.970,00
18	RC Repair Welding Erection Block SS 1A P	P	1,0	49.420,00
19	RC Repair Welding Erection Block SS 1A S	Q	5,0	247.100,00
20	RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R	3,0	148.260,00
21	Erection Vacuum Test Erection Block SS 1 A P	S	17,0	840.140,00
22	Erection Vacuum Test Erection Block SS 1 A S	T	10,0	494.200,00
23	Finishing RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R1	3,0	148.260,00
24	Finishing Erection Vacuum Test Erection Block SS 1 A P	S1	6,0	296.520,00
25	Finishing Erection Vacuum Test Erection Block SS 1 A S	T1	5,0	247.100,00
Total				21.522.410,00

Table 6. Summary of Acceleration Costs in the SS 1A Assembly Block Process

No	Description	Activity	Total Jo	Acceleration Cost (Rp)
1	Prepare Grand Assembly Loading & Adjusting Block SS 1A P/S	A	-	-
2	Grand Assembly Loading & Adjusting Grand Block SS 1A P	B	-	-
3	Grand Assembly Loading & Adjusting Grand Block SS 1A S	C	-	-
4	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A P	B1	-	-
5	Finishing Grand Assembly Loading & Adjusting Grand Block SS 1A S	C1	-	-
6	Grand Assembly Fitting Grand Block SS 1A S X Grand Block SS 1A P	D	4	197.680,00
7	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	25,5	1.260.210,00
8	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	6,0	296.520,00
9	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	3,0	148.260,00
10	Erection Loading & Adjusting Erection Block SS 1A P	H	8,0	395.360,00

No	Description	Activity	Total Jo	Acceleration Cost (Rp)
11	Erection Loading & Adjusting Erection Block SS 1A S	I	8,5	420.070,00
12	Erection Fitting Erection Block SS 1A P X DB 1 P	J	24,5	1.210.790,00
13	Erection Fitting Erection Block SS 1A S X DB 1 S	K	16,0	790.720,00
14	Erection Welding Erection Block SS 1A P X DB 1 P	L	19,5	963.690,00
15	Erection Welding Erection Block SS 1A S X DB 1 S	M	16,5	815.430,00
16	RC Repair Fitting Erection Block SS 1A S	N	3,0	148.260,00
17	RC Repair Tutup Opening Lambung Opening Lambung Block SS 1A S	O	-	-
18	RC Repair Welding Erection Block SS 1A P	P	-	-
19	RC Repair Welding Erection Block SS 1A S	Q	-	-
20	RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R	-	-
21	Erection Vacuum Test Erection Block SS 1 A P	S	6,0	296.520,00
22	Erection Vacuum Test Erection Block SS 1 A S	T	-	-
23	Finishing RC untuk Repair Alur Las Tank Test Erection Block SS 1A P	R1	-	-
24	Finishing Erection Vacuum Test Erection Block SS 1 A P	S1	-	-
25	Finishing Erection Vacuum Test Erection Block SS 1 A S	T1	-	-
Total				6.943.510,00

From tables above. the acceleration cost for the Block SS 1A assembly process is not for all activities, but there are only a few activities that can be accelerated based on overtime efforts, so the total cost required for acceleration is Rp. 6,943,510.00. Table 7 below shows comparison of time and cost in the SS 1A assembly block process.

Table 7 Comparison of Time and Cost in the SS 1A Assembly Block Process

No	Description	Activity	Normal Cost	Acceleration Cost	Normal Time (Day)	Acceleration Time (Day)
1	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	2.322.740,00	3.582.950,00	8	4
2	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	642.460,00	938.980,00	2	1
3	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	518.910,00	667.170,00	2	1
4	Erection Fitting Erection Block SS 1A P X DB 1 P	J	2.248.610,00	3.459.400,00	3	1
5	Erection Fitting Erection Block SS 1A S X DB 1 S	K	1.828.540,00	2.619.260,00	3	1
6	Erection Welding Erection Block SS 1A P X DB 1 P	L	1.952.090,00	2.915.780,00	7	3
7	Erection Welding Erection Block SS 1A S X DB 1 S	M	2.199.190,00	3.014.620,00	7	3
8	RC Repair Fitting Erection Block SS 1A S	N	2.001.510,00	2.149.770,00	2	1
9	Erection Vacuum Test Erection Block SS 1 A P	S	840.140,00	1.136.660,00	2	1

Table 8 Comparison of Time and Cost in the SS 1A Assembly Block Process

No	Description	Activity	Normal Cost	Acceleration Cost	Normal Time (Day)	Acceleration Time (Day)
1	Grand Assembly Welding Grand Block SS 1A S X Grand Block SS 1A P	E	2.322.740,00	3.582.950,00	8	4
2	Grand Assembly Vacuum Test Grand Assembly Block SS 1A P	F	642.460,00	938.980,00	2	1

No	Description	Activity	Normal Cost	Acceleration Cost	Normal Time (Day)	Acceleration Time (Day)
3	Grand Assembly Vacuum Test Grand Assembly Block SS 1A S	G	518.910,00	667.170,00	2	1
4	Erection Fitting Erection Block SS 1A P X DB 1 P	J	2.248.610,00	3.459.400,00	3	1
5	Erection Fitting Erection Block SS 1A S X DB 1 S	K	1.828.540,00	2.619.260,00	3	1
6	Erection Welding Erection Block SS 1A P X DB 1 P	L	1.952.090,00	2.915.780,00	7	3
7	Erection Welding Erection Block SS 1A S X DB 1 S	M	2.199.190,00	3.014.620,00	7	3
8	RC Repair Fitting Erection Block SS 1A S	N	2.001.510,00	2.149.770,00	2	1
9	Erection Vacuum Test Erection Block SS 1 A P	S	840.140,00	1.136.660,00	2	1

From the calculation above, the total acceleration cost can be determined using the following examples. For Activity E (Grand Assembly Welding Grand Block SS 1A S × Grand Block SS 1A P), the normal duration is 8 days with a normal cost of Rp 2,322,740. The crash duration is reduced to 4 days with a crash cost of Rp 3,582,950. Therefore, the maximum time reduction is 4 days (8 – 4), and the crash cost per day saved is calculated as (Rp 3,582,950 – Rp 2,322,740) / 4 = Rp 315,052.50 per day.
Meanwhile, for Activity F (Grand Assembly Vacuum Test Grand Assembly Block SS 1A P), the normal duration is 2 days with a normal cost of Rp 642,460, while the crash duration is 1 day with a crash cost of Rp 938,980. The maximum reduction in time is 1 day (2 – 1), resulting in a crash cost per day saved of (Rp 938,980 – Rp 642,460) / 1 = Rp 296,520 per day.

3.2 S Curved

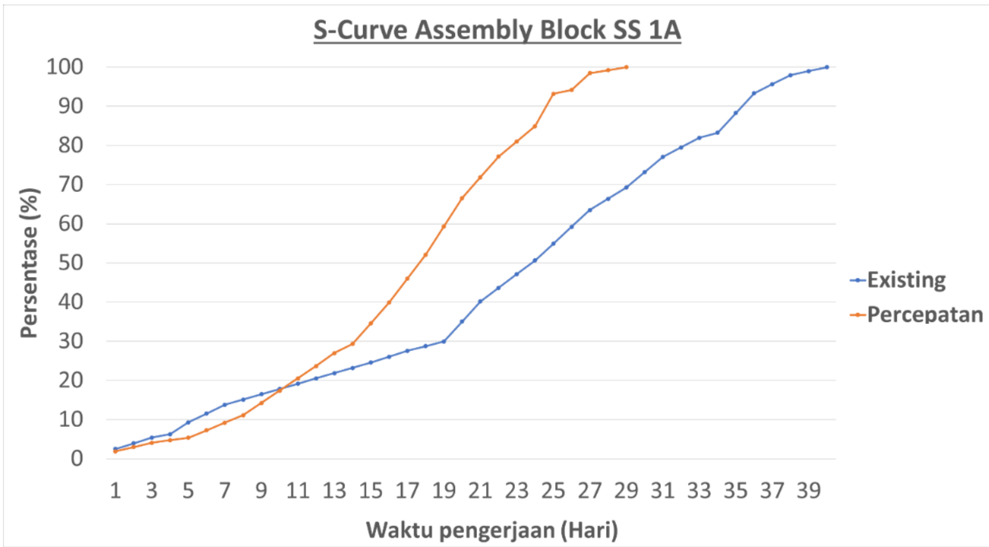

Figure 7. S-Curve Block SS 1A Hospital Ship Project

The S curve above explains that the blue dotted line shows the initial project duration before acceleration or the time in existing conditions, while the orange line shows the project duration after acceleration, namely 27 days.

4. CONCLUSION

The conclusions drawn from the research in the thesis entitled "Cost Analysis of Assembly Block Side Shell 1A (SS 1A) Acceleration Using the Critical Path Method (CPM) in the Hospital Ship Project" include several points that outline the answers to the research questions, including the following:

1) The Critical Path Method (CPM) was used to analyze scheduling problems in the SS 1A Assembly Block process, which has 25 activities.
2) The total wages before acceleration were Rp 21,522,410. After acceleration, they increased by Rp 28,465,920, resulting in an acceleration cost of Rp 6,943,510, using overtime acceleration.
3) The acceleration of the SS 1A Assembly Block process prioritized activities on the critical path, as the critical path is the longest-duration activity in the SS 1A Assembly Block process.

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