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Network Planning Analysis on Loading and Unloading of the MV Future Ocean 14,514 DWT at Semayang Port

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KEYWORDS
CPM
PERT
Manpower
Manhour
Efficiency

ABSTRACT – The process of loading and unloading ships is a critical activity in the logistics chain that impacts the efficiency and operational costs of ports. This study aims to evaluate the use of Network Planning methods in planning and controlling the time of the ship loading and unloading process. The research was conducted using historical data on the loading and unloading times of ships, as well as related activity schedules at Semayang Port, Balikpapan. This study adopts an approach by analyzing the application of network planning on the unloading process of the MV Future Ocean 14,514 DWT ship in the form of an S-Curve, then analyzing alternative critical paths along with duration acceleration using the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) on days (conditions) with better work weight consistency. Additionally, it analyzes how this affects manpower and manhour efficiency. The results of this study indicate that the application of the CPM and PERT methods led to a reduction in job duration from 1.408 minutes to 1.227 minutes using CPM, and 1.224,67 minutes using PERT. Based on the duration acceleration, the need for additional manpower increased from 21 to 24, resulting in a -14% decrease in manpower efficiency. The total manhour value changed from 3.941,28 MH to 3.936 MH with a 0,13% increase in manhour efficiency for CPM, and 3.916,8 MH with a 0,62% increase in manhour efficiency for PERT.

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INTRODUCTION

Ports are one of the important infrastructures in supporting a country's economic and trade activities. The ship loading and unloading process is one of the crucial aspects that influences port efficiency and productivity, as well as affecting service user satisfaction at the end-user point, however in actual conditions there are many delays in the ship loading and unloading process, thus disrupting the supply chain and increasing operational costs. The MV Future Ocean with 14,514 DWT is one of the ships operating at Semayang Port, Balikpapan, which is the gateway to trade in East Kalimantan. The application of network planning techniques in the ship loading and unloading process aims to optimize work flow, reduce waiting time and increase operational efficiency. Based on previous related research, it shows that the network planning method has been widely applied to project work, including building construction, production, equipment repair, installation and ship building projects. From the application of the network planning method that has been carried out [1] in a restaurant construction project, the use of the CPM and PERT methods shows that the application of these methods can provide increased operational efficiency and effectiveness in terms of time and cost. [2] implemented PERT and CPM on a ship building project and concluded that this application could help work planning with a small risk of delay. Study from [3] and [4] that applied the CPM method and the crashing method concluded that accelerating duration with CPM needed to be supported by additional workforce.

This method is still rarely applied to the ship loading and unloading work process, where the work can be categorized as project work which has a specific objective, has time limits, and requires resource coordination to achieve the work objectives [5]. This is the reason why researchers are interested in conducting research entitled Analysis of the Application of Network Planning in the Loading and Unloading Process of the MV Future Ocean 14,514 DWT Ship at Semayang Port, Balikpapan, to be able to apply the network planning method and see what efficiency results from this method when applied to the ship loading and unloading process.

This research can make a new contribution by applying the network planning critical path method and project review and evaluation technique specifically in the loading and unloading work process of the MV Future Ocean 14,514 DWT ship at Semayang Port, Balikpapan with a focus on the characteristics of the ship and operational conditions at the port. to provide more accurate and relevant results. Apart from that, this research will also be able to provide practical recommendations that can be implemented by port managers or companies to increase

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operational efficiency and reduce ship waiting times. With an integrated approach, this research can also provide benefits to the port industry and logistics industry in Indonesia.

METHOD

The unloading process of the MV Future Ocean 14,514 DWT ship took 10 days from 23 July 2024 to 02 August 2024, however there were only four (4) days that had a full 24 hour work duration, which is the object of this research. These four days are further mentioned as Condition 1, Condition 2, Condition 3, and Condition 4:

Table 1. Research Object

No.	Condition	Date	Number of Work Items	Work Volume (packages)
1	Condition 1	July 26, 2025	25	91
2	Condition 2	July 27, 2024	27	110
3	Condition 3	July 28, 2024	24	137
4	Condition 4	August 01, 2024	18	74

Source: Researcher

The data for each condition is identified as a work item and to provide efficiency in writing, an item code is given to each work item, and additional information is given to work items that experience repetition in the form of a serial number for the work item:

Table 2. Work Item Code

No.	Work Item	Work Item Code
1	*Discharge*	A
2	*Truck Waiting*	B
3	*Break Time*	C
4	*Rest Time*	D
5	*Meal Time*	E
6	*Tool Box Meeting*	F
7	*Crane Setting*	G
8	*Forklift Transfer*	H
9	*Upper Deck Cleaning*	I
10	*Open Pontoon and Unlashing*	J
11	*Cargo Shifting*	K

Source: Researcher

Data Collection

Data collection is carried out by obtaining data on work that has been completed and conducting interviews from related companies.

Table 3. Data Collection

No.	Data	Source / Method	Data Type
1	Job Type	Company	Secondary
2	Work Volume	Company	Secondary
3	Data on Optimistic Duration, Most Likely Duration, and Pessimistic Duration of Work	Company / Interview	Primary
4	Predecessor Work Item Data	Company / Interview	Primary
5	Manpower Allocation Data	Company / Interview	Primary

Source: Researcher

Data Processing Using S-Curves

The data that was previously obtained was then processed using the S-curve method in conditions 1 to 4 to determine the weight of the duration of each type of work. The equation used to create the s-curve is [5]:

$$\text{Work Weight} = \frac{\text{Duration of Work Unit}}{\text{Duration Recapitulation}} \text{ X } 100\% \quad (1)$$

Standard Deviation Calculation

At this calculation stage, the standard deviation of the weight of work per hour in each condition is calculated using Microsoft Excel software. This calculation was carried out to find out which conditions had more consistent work weight data values per hour. After calculating the standard deviation, the next step is to calculate the critical path method, program evaluation and review technique, and efficiency only in conditions that have better consistency.

Critical Path Method Calculation

Next, calculations are carried out only on condition data that has been determined using the Critical Path Method. The equations used in the Critical Path Method calculations [7]

$$EF = ES + \text{Duration} \quad (2)$$

$$LS = LF - \text{Duration} \quad (3)$$

$$TF = LF - ES - \text{Duration} \quad (4)$$

Explanation:

EF	: Earliest Finish
ES	: Earliest Start
LS	: Latest Start
LF	: Latest Finish
TF	: Total Float
Duration	: Time Required

Program Evaluation and Review Technique Calculation

In the application of the Program Evaluation and Review Technique, calculations are carried out to produce estimated time values, standard deviation, variance of estimated time, and probability of success on time using the equation [2]:

$$Te = \frac{a+4m+b}{6} \quad (5)$$

$$S = \frac{b-a}{6} \quad (6)$$

$$V(Te) = S^2 \quad (7)$$

$$Z = \frac{Td - Te}{S} \quad (8)$$

Explanation:

Te	= Time Estimation
a	= Optimistic Duration
m	= Most Likely Duration
b	= Pessimistic duration
S	= Standard Deviation
V(Te)	= Variance
Z	= Probability of Timely Completion
Td	= Normal Duration

Efficiency Calculation

The calculation of the labor coefficient value in the initial data and changes in the manpower value are carried out using the equation [8]

$$\text{Coefficient} = \frac{\text{Duration X Manpower}}{\text{Volume X Work Time}} \tag{9}$$

The calculation of the manhour value is carried out using the following equation [8]:

$$\text{Duration} = \frac{\sum \text{manhour}}{\text{Manpower X Work Time}} \tag{10}$$

Then the resulting manhour efficiency value is calculated using the equation [9] and manpower efficiency with Equation [10]:

$$\text{Efficiency} = \frac{(\text{MH basic} - \text{MH acceleration})}{\text{MH basic}} \text{ X } 100\% \tag{11}$$

$$\text{MP Efficiency} = \frac{\text{Necessary MP}}{\text{Actual MP}} \tag{12}$$

Explanation:
Necessary MP = Amount of Manpower required
Actual MP = Actual Amount of Manpower Allocation

Research Variables

The following are the variables used in the research:

Table 4. Research Variable

Variable	Variable Type	Variation
Independent	Process	Work Duration
		Work Volume
	Resource	Manhour
		Manpower
Dependent	Efficiency	Work Duration
		Manhour & Manpower

Source: Researcher

RESULTS AND DISCUSSION

Based on the data obtained in Condition 1, the weight of the work duration is calculated using equation (8), then the weight is distributed according to the implementation time of each work item and the total weight per hour is added up. After that, the total hourly weights are added up cumulatively to become a reference in producing the S-curve of Condition 1: [11]]revealed that the S-curve can show the cumulative growth of work progress. The S-curve produced based on the weight of work duration per hour which is added up cumulatively in Figure 1 shows a weight growth that tends to be inconsistent as seen in the curve line which has several spikes in variation. This was caused by a decrease in growth at the 3rd hour, 9th hour, 11th hour and 13th hour, then a significant increase occurred at the 10th hour and 14th hour, while weight growth at others tend to be stable. From the total weight per hour in Condition 1, descriptive analysis was then carried out in the form of calculating a mean value of 0.0417 and a standard deviation value of 0.00938.

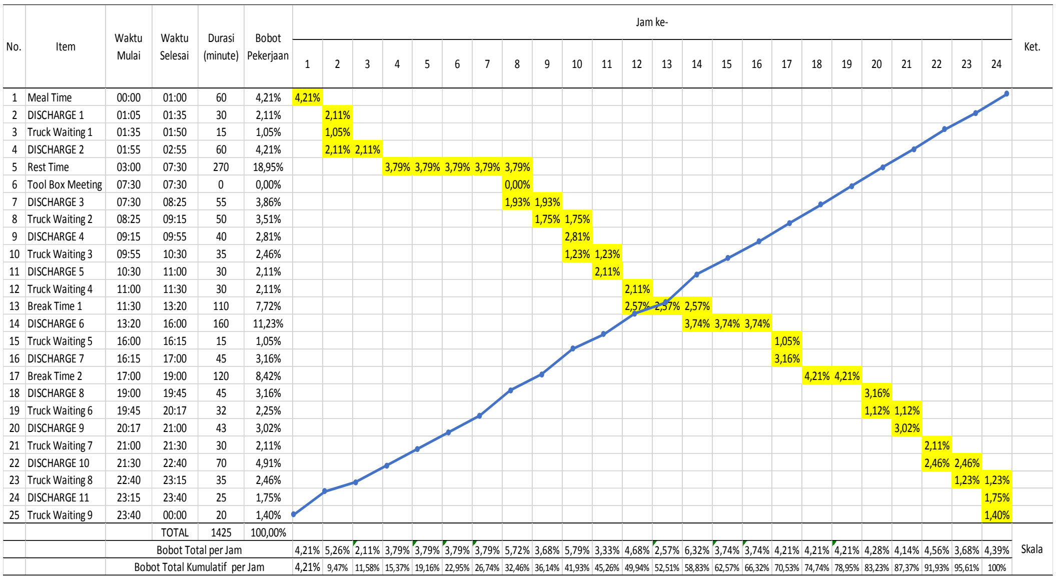


Figure 1. S-Curve of Condition 1

Based on the data obtained in Condition 2, the weight of the work duration is calculated using equation (8), which is then distributed according to the implementation time of each work item and the total weight per hour is added up. After that, the total hourly weights are added up cumulatively to become a reference in producing the S-curve of Condition 2:

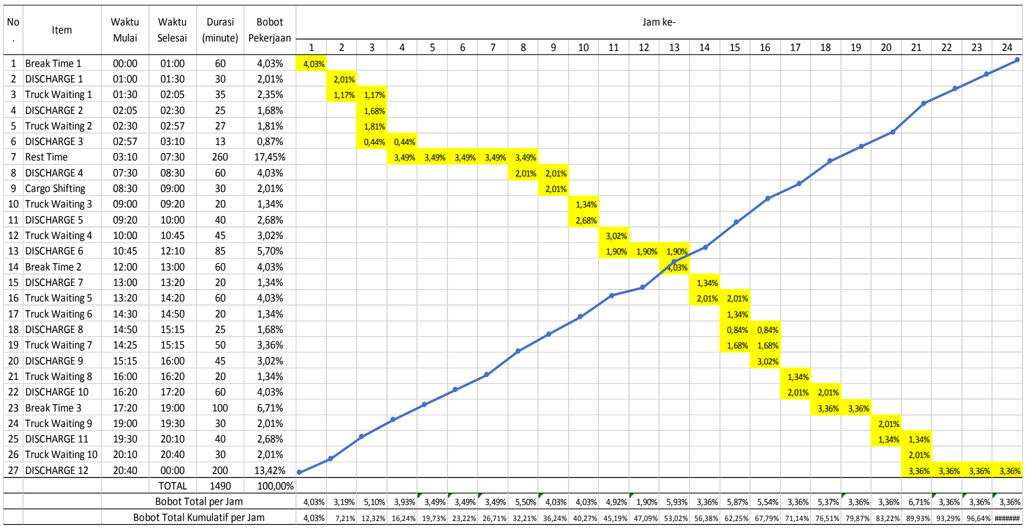
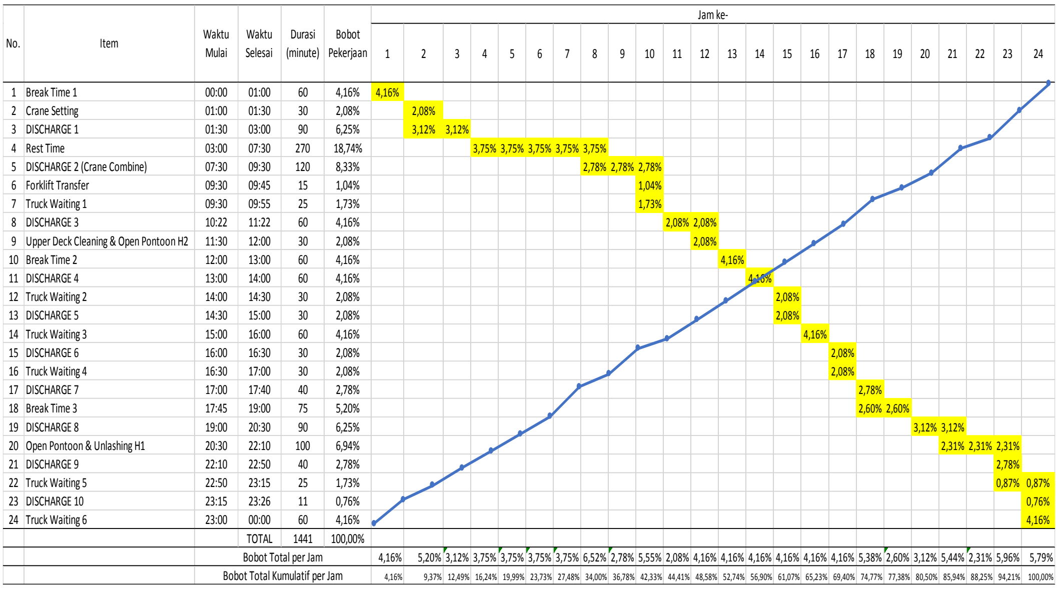


Figure 2. S-Curve of Condition 2

[11] revealed that the S-curve can show the cumulative growth of work progress. The S-curve produced based on the weight of work duration per hour which is added up cumulatively in Figure 2 shows that there is a weight growth that tends to be inconsistent, visible in the curve line which has several spikes in variation. This was caused by a decrease in growth at the 12th, 14th and 17th hours, then a significant increase occurred at the 13th and 21st hours, while weight growth at other hours tended to be stable. From the total weight per hour in Condition 2, descriptive analysis was then carried out in the form of calculating a mean value of 0.0417 and a standard deviation value of 0.01165.

Based on the data obtained in Condition 3, the weight of the work duration is calculated using equation (8), which is then distributed according to the implementation time of each work item and the total weight per hour is added up. After that, the total hourly weights are added up cumulatively to become a reference in producing the S-curve of Condition 3:

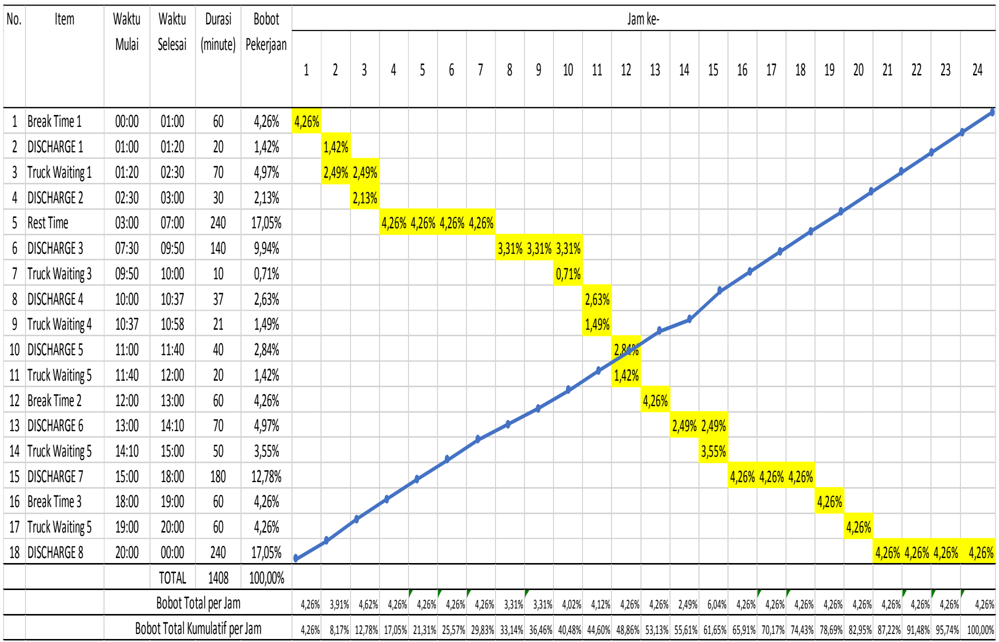


No.	Item	Waktu Mulai	Waktu Selesai	Durasi (minute)	Bobot Pekerjaan	Jam ke-																							
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Break Time 1	00:00	01:00	60	4,16%	4,16%																							
2	Crane Setting	01:00	01:30	30	2,08%		2,08%																						
3	DISCHARGE 1	01:30	03:00	90	6,25%		3,12%	3,12%																					
4	Rest Time	03:00	07:30	270	18,74%				3,75%	3,75%	3,75%	3,75%	3,75%																
5	DISCHARGE 2 (Crane Combine)	07:30	09:30	120	8,33%								2,78%	2,78%	2,78%														
6	Forklift Transfer	09:30	09:45	15	1,04%										1,04%														
7	Truck Waiting 1	09:30	09:55	25	1,73%										1,73%														
8	DISCHARGE 3	10:22	11:22	60	4,16%											2,08%	2,08%												
9	Upper Deck Cleaning & Open Pontoon H2	11:30	12:00	30	2,08%												2,08%												
10	Break Time 2	12:00	13:00	60	4,16%													4,16%											
11	DISCHARGE 4	13:00	14:00	60	4,16%														4,16%										
12	Truck Waiting 2	14:00	14:30	30	2,08%															2,08%									
13	DISCHARGE 5	14:30	15:00	30	2,08%															2,08%									
14	Truck Waiting 3	15:00	16:00	60	4,16%																4,16%								
15	DISCHARGE 6	16:00	16:30	30	2,08%																	2,08%							
16	Truck Waiting 4	16:30	17:00	30	2,08%																	2,08%							
17	DISCHARGE 7	17:00	17:40	40	2,78%																		2,78%						
18	Break Time 3	17:45	19:00	75	5,20%																		2,60%	2,60%					
19	DISCHARGE 8	19:00	20:30	90	6,25%																				3,12%	3,12%			
20	Open Pontoon & Unlashing H1	20:30	22:10	100	6,94%																					2,31%	2,31%	2,31%	
21	DISCHARGE 9	22:10	22:50	40	2,78%																							2,78%	
22	Truck Waiting 5	22:50	23:15	25	1,73%																							0,87%	0,87%
23	DISCHARGE 10	23:15	23:26	11	0,76%																								0,76%
24	Truck Waiting 6	23:00	00:00	60	4,16%																								4,16%
			TOTAL	1441	100,00%																								
		Bobot Total per Jam				4,16%	5,20%	3,12%	3,75%	3,75%	3,75%	3,75%	6,52%	2,78%	5,55%	2,08%	4,16%	4,16%	4,16%	4,16%	4,16%	4,16%	5,38%	2,60%	3,12%	5,44%	2,31%	5,96%	5,79%
		Bobot Total Kumulatif per Jam				4,16%	9,37%	12,49%	16,24%	19,99%	23,73%	27,48%	34,00%	36,78%	42,33%	44,41%	48,58%	52,74%	56,90%	61,07%	65,23%	69,40%	74,77%	77,38%	80,50%	85,94%	88,25%	94,21%	100,00%

Figure 3. S-Curve of Condition 3

[11] revealed that the S-curve can show the cumulative growth of work progress. The S-curve produced based on the weight of work duration per hour which is added up cumulatively in Figure 3 shows that there is a weight growth that tends to be inconsistent, visible in the curve line which has several spikes in variation. This is caused by a significant decrease in growth at the 9th hour, 11th hour, 19th hour and 22nd hour, then a significant increase occurs at the 8th hour, 10th hour, 21st hour, and the 22nd hour, while weight growth at other hours tends to be stable. From the total weight per hour in Condition 3, descriptive analysis was then carried out in the form of calculating a mean value of 0.0417 and a standard deviation value of 0.01189.

Based on the data obtained in Condition 4, the weight of the work duration is calculated using equation (8), then the weight is distributed according to the implementation time of each work item and the total weight per hour is added up. After that, the total hourly weights are added up cumulatively to become a reference in producing the S-curve of Condition 4:



No.	Item	Waktu Mulai	Waktu Selesai	Durasi (minute)	Bobot Pekerjaan	Jam ke-																							
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Break Time 1	00:00	01:00	60	4,26%	4,26%																							
2	DISCHARGE 1	01:00	01:20	20	1,42%		1,42%																						
3	Truck Waiting 1	01:20	02:30	70	4,97%		2,49%	2,49%																					
4	DISCHARGE 2	02:30	03:00	30	2,13%			2,13%																					
5	Rest Time	03:00	07:00	240	17,05%				4,26%	4,26%	4,26%	4,26%																	
6	DISCHARGE 3	07:30	09:50	140	9,94%								3,31%	3,31%	3,31%														
7	Truck Waiting 3	09:50	10:00	10	0,71%										0,71%														
8	DISCHARGE 4	10:00	10:37	37	2,63%											2,63%													
9	Truck Waiting 4	10:37	10:58	21	1,49%											1,49%													
10	DISCHARGE 5	11:00	11:40	40	2,84%												2,84%												
11	Truck Waiting 5	11:40	12:00	20	1,42%												1,42%												
12	Break Time 2	12:00	13:00	60	4,26%													4,26%											
13	DISCHARGE 6	13:00	14:10	70	4,97%														2,49%	2,49%									
14	Truck Waiting 5	14:10	15:00	50	3,55%															3,55%									
15	DISCHARGE 7	15:00	18:00	180	12,78%																4,26%	4,26%	4,26%						
16	Break Time 3	18:00	19:00	60	4,26%																			4,26%					
17	Truck Waiting 5	19:00	20:00	60	4,26%																				4,26%				
18	DISCHARGE 8	20:00	00:00	240	17,05%																					4,26%	4,26%	4,26%	4,26%
			TOTAL	1408	100,00%																								
		Bobot Total per Jam				4,26%	3,91%	4,62%	4,26%	4,26%	4,26%	4,26%	3,31%	3,31%	4,02%	4,12%	4,26%	4,26%	2,49%	6,04%	4,26%	4,26%	4,26%	4,26%	4,26%	4,26%	4,26%	4,26%	4,26%
		Bobot Total Kumulatif per Jam				4,26%	8,17%	12,78%	17,05%	21,31%	25,57%	29,83%	33,14%	36,46%	40,48%	44,60%	48,86%	53,13%	55,61%	61,65%	65,91%	70,17%	74,43%	78,69%	82,95%	87,22%	91,48%	95,74%	100,00%

Figure 4. S-Curve of Condition 4

[11] revealed that the S-curve can show the cumulative growth of work progress. The S-curve produced based on the weight of work duration per hour which is added up cumulatively in Figure 4 shows a fairly consistent weight growth because the curve line does not experience much change in progress growth. This happened because there was only a significant decrease at the 13th hour, and a significant increase at the 14th hour, while

weight growth at the other hours tended to be stable. From the total weight per hour in Condition 4, descriptive analysis was then carried out in the form of calculating a mean value of 0.0417 and a standard deviation value of 0.00598.

Descriptive analysis was carried out on the total weight per hour in each condition:

Table 5. Descriptive Analysis

Hour	Work Weight per Hour			
	Condition 1	Condition 2	Condition 3	Condition 4
1	0,0421	0,0403	0,0416	0,0426
2	0,0526	0,0319	0,0520	0,0391
3	0,0211	0,0510	0,0312	0,0462
4	0,0379	0,0393	0,0375	0,0426
5	0,0379	0,0349	0,0375	0,0426
6	0,0379	0,0349	0,0375	0,0426
7	0,0379	0,0349	0,0375	0,0426
8	0,0572	0,0550	0,0652	0,0331
9	0,0368	0,0403	0,0278	0,0331
10	0,0579	0,0403	0,0555	0,0402
11	0,0333	0,0492	0,0208	0,0412
12	0,0468	0,0190	0,0416	0,0426
13	0,0257	0,0593	0,0416	0,0426
14	0,0632	0,0336	0,0416	0,0249
15	0,0374	0,0587	0,0416	0,0604
16	0,0374	0,0554	0,0416	0,0426
17	0,0421	0,0336	0,0416	0,0426
18	0,0421	0,0537	0,0538	0,0426
19	0,0421	0,0336	0,0260	0,0426
20	0,0428	0,0336	0,0312	0,0426
21	0,0414	0,0671	0,0544	0,0426
22	0,0456	0,0336	0,0231	0,0426
23	0,0368	0,0336	0,0596	0,0426
24	0,0439	0,0336	0,0579	0,0426
Mean	0,0417	0,0417	0,0417	0,0417
Standard Deviation	0,0094	0,0117	0,0119	0,0060

Source: Researcher

Based on Table 5 which contains a comparison of the mean value and standard deviation value for each condition, it shows that all conditions have the same mean value, namely 0.0417, while the lowest standard deviation value is in Condition 4 at 0.0060. According to [12] the standard deviation value shows the consistency of the data, where the standard deviation value is lower, closer to zero, meaning the data value has low and consistent variation, and vice versa, if the standard deviation value is closer to the mean value, it means the data has high and inconsistent variation. In this case the weight of work per hour in Condition 4 has the best consistency, so that the next step in applying the critical path method and program evaluation and review technique, as well as efficiency calculations will be carried out only in Condition 4.

In this sub-chapter, calculations are carried out using the critical path method, and the diagram is drawn for Condition 4 from data previously obtained by filling in a questionnaire related to the predecessor work item for each work item:

Table 6. Work Item on Condition 4

No	Work Item	Item Code	Predecessor Work
1	*Break Time 1*	C1	-
2	*Discharge 1*	A1	C1
3	*Truck Waiting 1*	B1	C1
4	*Discharge 2*	A2	A1 & B1
5	*Rest Time*	D	A2
6	*Discharge 3*	A3	D
7	*Truck Waiting 3*	B2	D
8	*Discharge 4*	A4	A3 & B2
9	*Truck Waiting 4*	B3	A3 & B2

No	Work Item	Item Code	Predecessor Work
10	*Discharge 5*	A5	A4 & B3
11	*Truck Waiting 5*	B4	A4 & B3
12	*Break Time 2*	C2	A5 & B4
13	*Discharge 6*	A6	C2
14	*Truck Waiting 5*	B5	C2
15	*Discharge 7*	A7	A6 & B5
16	*Break Time 3*	C3	A7
17	*Truck Waiting 5*	B6	C3
18	*Discharge 8*	A8	C3

Source: Researcher

The earliest finish (EF) value is calculated using equation (1), the latest start (LS) value using equation (2), and the total float (TF) value using equation (3). The following is an example of the calculation carried out on the Discharge 1 (A1) work item which is presented and marked in red on Table 7:

Table 7. CPM Calculation on Condition 4

No	Work Item	Predecessor Work	Duration	ES	EF	LS	LF	TF
1	C1	-	60	0	60	0	60	0
2	A1	C1	20	60	80	110	130	50
3	B1	C1	70	60	130	60	130	0
4	A2	A1 & B1	30	130	160	130	160	0
5	D	A2	240	160	400	160	400	0
6	A3	D	140	400	540	400	540	0
7	B2	D	10	400	410	530	540	130
8	A4	A3 & B2	37	540	577	540	577	0
9	B3	A3 & B2	21	540	561	556	577	16
10	A5	A4 & B3	40	577	617	577	617	0
11	B4	A4 & B3	20	577	597	597	617	20
12	C2	A5 & B4	60	617	677	617	677	0
13	A6	C2	70	677	747	677	747	0
14	B5	C2	50	677	727	697	747	20
15	A7	A6 & B5	180	747	927	747	927	0
16	C3	A7	60	927	987	927	987	0
17	B6	C3	60	987	1047	1167	1227	180
18	A8	C3	240	987	1227	987	1227	0

Source: Researcher

Based on the calculation results listed in Table 7, it shows that using the CPM method the duration of work has accelerated by 181 minutes from the original 1,408 minutes to 1,227 minutes. Then the critical path method diagram from Condition 4 is generated:

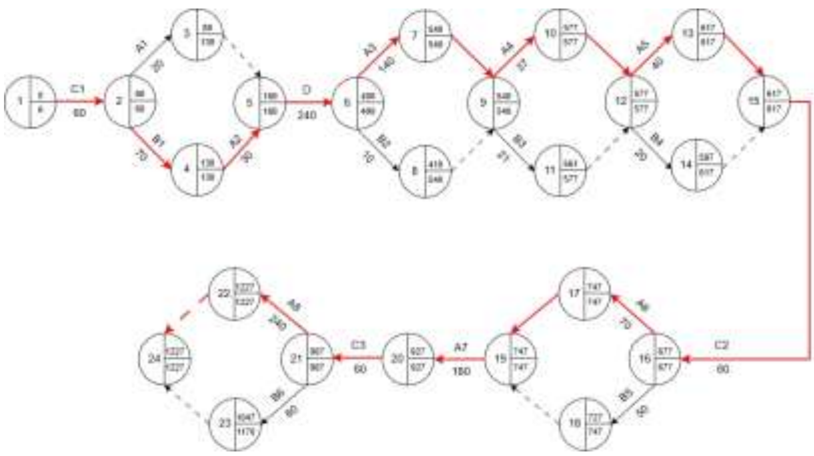


Figure 5. CPM Diagram of Condition 4

Figure 5 shows that the critical path or path that has a total float value (TF) = 0 is on work item C1-B1-A2-D-A3-A4-A5-C2-A6-A7-C3-A8 or Break Time 1 - Truck Waiting 1 - Discharge 2 - Rest Time - Discharge 3 - Discharge 4 - Discharge 5 - Break Time 2 - Discharge 6 - Discharge 7 - Break Time 3 - Discharge 8.

This shows that these work items cannot experience delays or delays which will slow down the duration of work completion. Meanwhile, work items that have a total float (TF) value > 0 are work items A1, B2, B3, B4, B5, B6 or Discharge 1, Truck Waiting 2, Truck Waiting 3, Truck Waiting 4, Truck Waiting 5, and Truck Waiting 6. So that these work items can be allowed for delays or maximum delays in accordance with the total float value produced so that the duration of work completion does not experience delays. So based on information regarding the relationship between each job, it causes an acceleration in the duration of work and the emergence of a critical path for work items that have a total float value (TF) = 0. This is in line with the research results of [13] which shows that the implementation of CPM can accelerate project durations that are shorter than the initial duration.

Then the initial step of calculating the PERT method in Condition 4 is carried out using the normal duration value (Td) as well as interview data related to the optimistic time value (a), the most likely time (m), and the pessimistic time (b) to produce the estimated time value (Te) using equation (4), the standard deviation value (S) using equation (5), and the variance value Te (V(Te)) using equation (6). Work item B1 or Truck Waiting 1 is marked in red Table 8 and calculation example is given:

Table 8. PERT Calculation on Condition 4

No	Item Code	Td Duration	a	m	b	Te	S	V(Te)
1	C1	60	60	60	60	60,00	0,00	0,00
2	A1	20	15	20	22	19,50	1,17	1,36
3	B1	70	67	70	72	69,83	0,83	0,69
4	A2	30	25	30	32	29,50	1,17	1,36
5	D	240	240	240	240	240,00	0,00	0,00
6	A3	140	137	140	142	139,83	0,83	0,69
7	B2	10	8	10	12	10,00	0,67	0,44
8	A4	37	35	37	39	37,00	0,67	0,44
9	B3	21	18	21	23	20,83	0,83	0,69
10	A5	40	36	40	42	39,67	1,00	1,00
11	B4	20	17	20	22	19,83	0,83	0,69
12	C2	60	60	60	60	60,00	0,00	0,00
13	A6	70	65	70	72	69,50	1,17	1,36
14	B5	50	47	50	52	49,83	0,83	0,69
15	A7	180	175	180	182	179,50	1,17	1,36
16	C3	60	60	60	60	60,00	0,00	0,00
17	B6	60	58	60	62	60,00	0,67	0,44
18	A8	240	237	240	242	239,83	0,83	0,69

Source: Researcher

Based on the results of the estimated time value (Te) in Table 8, which then acts as a duration value, the earliest finish (EF) value is then calculated using equation (1), the latest start (LS) value using equation (2), and the total float value (TF) using equation (3):

Table 9. PERT Calculation on Critical Path of Condition 4

No	Item Code	Predecessor Work	Te Duration	ES	EF	LS	LF	TF
1	C1	-	60	0	60	0	60	0
2	A1	C1	19,5	60	79,5	110,33	129,83	50
3	B1	C1	69,83	60	129,83	60	129,83	0
4	A2	A1 & B1	29,5	129,83	159,33	129,83	159,33	0
5	D	A2	240	159,33	399,33	159,33	399,33	0
6	A3	D	139,83	399,33	539,17	399,33	539,17	0
7	B2	D	10	399,33	409,33	529,17	539,17	130
8	A4	A3 & B2	37	539,17	576,17	539,17	576,17	0
9	B3	A3 & B2	20,83	539,17	560	555,33	576,17	16
10	A5	A4 & B3	39,67	576,17	615,83	576,17	615,83	0
11	B4	A4 & B3	19,83	576,17	596	596	615,83	20

No	Item Code	Predecessor Work	Te Duration	ES	EF	LS	LF	TF
12	C2	A5 & B4	60	615,83	675,83	615,83	675,83	0
13	A6	C2	69,5	675,83	745,33	675,83	745,33	0
14	B5	C2	49,83	675,83	725,67	695,5	745,33	20
15	A7	A6 & B5	179,5	745,33	924,83	745,33	924,83	0
16	C3	A7	60	924,83	984,83	924,83	984,83	0
17	B6	C3	60	984,83	1044,83	1164,67	1224,67	180
18	A8	C3	239,83	984,83	1224,67	984,83	1224,67	0

Source: Researcher

From the calculations produced in Table 9, it is known that the application of the PERT method results in an acceleration of work duration from 1,408 minutes to 1,224.67 minutes. The critical path in the application of this method is the same as in the CPM method but has different ES, EF, LS, LF values due to the estimated time calculation.

The critical path or path that has a total float value (TF) = 0 is on work item C1-B1-A2-D-A3-A4-A5-C2-A6-A7-C3-A8 or Break Time 1 - Truck Waiting 1 - Discharge 2 - Rest Time - Discharge 3 - Discharge 4 - Discharge 5 - Break Time 2 - Discharge 6 - Discharge 7 - Break Time 3 - Discharge 8. This shows that these work items cannot experience delays or delays which will slow down the duration of work completion. Meanwhile, work items that have a total float (TF) value > 0 are work items A1, B2, B3, B4, B5, B6 or Discharge 1, Truck Waiting 2, Truck Waiting 3, Truck Waiting 4, Truck Waiting 5, and Truck Waiting 6. So that these work items can be allowed for delays or maximum delays in accordance with the total float value produced so that the duration of work completion does not experience delays. Then, from the results of these calculations, a PERT diagram is produced as follows:

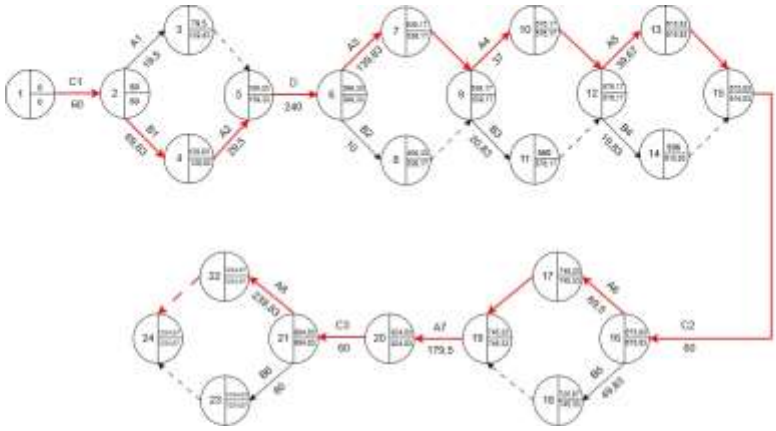


Figure 6. PERT Diagram of Condition 4

From Table 9 and Figure 6 shows that the work items on the critical path are C1-B1-A2-D-A3-A4-A5-C2-A6-A7-C3-A8. The estimated values of time (Te), standard deviation (S), normal duration (Td), and variance (V(Te)) on critical path work items are summarized in Table 10:

Table 10. PERT Probability Calculation on Condition 4

Item Code	Te	S	Td	V(Te)
C1	60,00	0,00	60	0,00
B1	69,83	0,83	70	0,69
A2	29,50	1,17	30	1,36
D	240,00	0,00	240	0,00
A3	139,83	0,83	140	0,69
A4	37,00	0,67	37	0,44
A5	39,67	1,00	40	1,00
C2	60,00	0,00	60	0,00
A6	69,50	1,17	70	1,36
A7	179,50	1,17	180	1,36
C3	60,00	0,00	60	0,00
A8	239,83	0,83	240	0,69

Item Code	Te	S	Td	V(Te)
∑	1224,67	7,67	1227,00	7,61

Source: Researcher

Based on Table 10, it can be seen that the total normal duration (Td) of work on the critical path is 1,227 minutes, the total estimated time (Te) value is 1,224.67 minutes, and the total standard deviation (S) value is 7.67. Next, the probability of completion on time is calculated using equation (7):

$$Z = \frac{1.227 - 1.224,67}{7,67} \tag{7}$$

$$Z = 0,3043$$

From the calculation results, it is obtained that the value Z = 0.3043 in the normal distribution table Z has a value of 0.1779, so the probability of completion on time 1,224.67 minutes is 1 - 0.1779 = 0.8221, with a percentage of 82.21%. It refers that the work in Condition 4 can be completed on time for 1,224.67 minutes with a probability of success of 82.21%. Based on information regarding the relationship between each job, this causes an acceleration in the duration of the job and the emergence of a critical path for work items that have a total float (TF) value = 0 with a probability of completion on time of 82.21%. This is in line with the research results [13] which shows that the implementation of PERT can accelerate project durations that are shorter than the initial duration with a relatively small probability of failure.

In this sub-chapter, calculations are carried out based on existing manpower data in Condition 4 to determine the coefficient value for each workforce which will then also be applied to determine the amount of new manpower needed after accelerating the duration of the CPM method and PERT method using equation (9) is exemplified by the type of labor labor and is applied to all types of labor:

Table 11. Coefficient Calculation of Existing Manpower

Labor	Working Time (minutes/day)	Manpower (people)	Duration (minute)	Volume (*packages*)	Labor coef.
Laborer	480	12	1.408	74	0,476
Crane Operator	480	3	1.408	74	0,119
Foreman	480	6	1.408	74	0,238
	Total	21			

Source: Researcher

After knowing the coefficient value for each worker listed in Table 11, the number of new workers resulting from the application of the CPM and PERT methods is calculated using the same equation but by changing the initial duration value to the resulting duration of acceleration:

Table 12. CPM Manpower Calculation

Labor	Working Time (minutes/day)	Manpower (people)	Duration (minute)	Volume (*packages*)	Labor coef.
Laborer	480	1.227	74	0,476	14
Crane Operator	480	1.227	74	0,119	3
Foreman	480	1.227	74	0,238	7
				Total	24

Source: Researcher

Table 13. PERT Manpower Calculation

Labor	Working Time (minutes/day)	Manpower (people)	Duration (minute)	Volume (*packages*)	Labor coef.
Laborer	480	1.224,67	74	0,476	14
Crane Operator	480	1.224,67	74	0,119	3
Foreman	480	1.224,67	74	0,238	7

Labor	Working Time (minutes/day)	Manpower (people)	Duration (minute)	Volume (*packages*)	Labor coef.
				Total	24

Source: Researcher

Based on the results of the calculation of the number of new manpower requirements listed in Table 12 and Table 13, it shows that after implementing CPM and implementing PERT in Condition 4, the duration accelerated, causing both to require an increase in the number of workers. The need of labor for workers has increased by two (2) manpower, for Foreman workers there has been an increase of one (1) manpower, while for Crane Operator workers there is no need for an increase in manpower requirements. Overall, the data resulting from the implementation of CPM and PERT experienced an increase of four (4) manpower from 21 people in the initial data, increasing to 24 people. This is in line with the research results [4] which concludes that work where the CPM or PERT method is applied requires additional workforce. The calculation results of manpower before and after the implementation of CPM and PERT are compared and depicted in Figure 7.

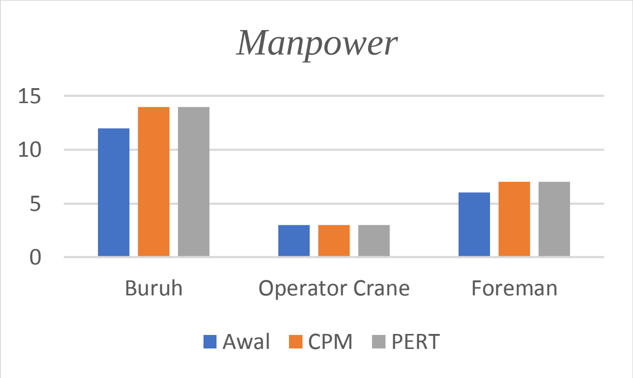


Figure 7. Comparison of Total Manpower
Source: Researcher

Based on Figure 7, shows that the results of implementing CPM and PERT resulted in changes in the number of manpower requirements for several types of labor. Both the Labor and Foreman workforce experienced a significant increase in the need for manpower, while the Crane Operator workforce did not require additional workforce.

In this sub-chapter, calculations are carried out based on existing condition 4 manpower data and data from new manpower calculations that have been carried out in the previous sub-chapter. This calculation is carried out to obtain the manhour value using equation (10) by changing the unit of duration value from minutes to hours to produce the manhour value. The calculation is modeled on the type of labor force and is applied to all types of labor force:

Table 14. Existing Manhour Calculation

Labor	Duration (hour)	Manpower (people)	Work Time (hour/day)	Manhour (MH)
Laborer	23,46	12	8	2.252,16
Crane Operator	23,46	3	8	563,04
Foreman	23,46	6	8	1.126,08
			Total	3.941,28

Source: Researcher

Table 15. CPM Manhour Calculation

Labor	Duration (hour)	Manpower (people)	Work Time (hour/day)	Manhour (MH)
Laborer	20,5	14	8	2.296
Crane Operator	20,5	3	8	492
Foreman	20,5	7	8	1.148
			Total	3.936

Source: Researcher

Table 16. PERT Manhour Calculation

Labor	Duration (hour)	Manpower (people)	Work Time (hour/day)	Manhour (MH)
Laborer	20,4	14	8	2.284,8
Crane Operator	20,4	3	8	489,6
Foreman	20,4	7	8	1.142,4
			Total	3.916,8

Source: Researcher

Based on the results of calculating the number of manhours in the initial data, data from the application of CPM and data from the application of PERT which experienced an acceleration in the duration of work and required additional manpower, it can be seen that this influenced the value of manhours which increased in the types of Labor and Foreman labor, while For Crane Operator workers, the value of manhours has decreased due to the acceleration in duration and these workers have not experienced an increase in the number of manpower. Overall, the CPM data shows a decrease of 5.28 MH from 3,941.28 MH to 3,936 MH. Meanwhile, the PERT results decreased by 24.48 MH from 3,941.28 MH to 3,916.8 MH. This is in line with the research results [9] that found a change in the total manhour value after implementing the network planning method. The calculation of the number of manhours produced before and after the implementation of CPM and PERT is compared and illustrated in Figure 8.

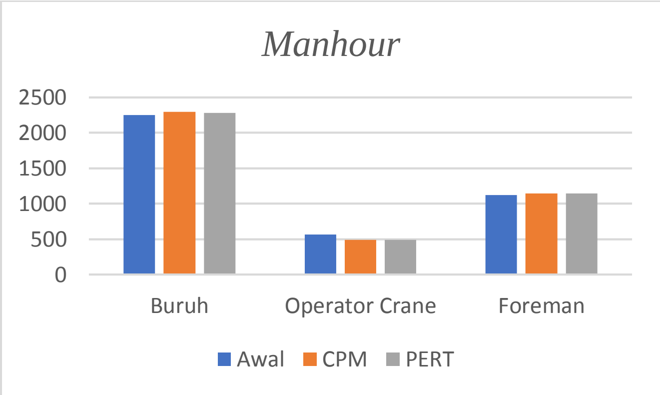


Figure 8. Comparison of Total Manhour
Source: Researcher

Based on Figure 8, it shows that there are no significant changes resulting from the implementation of CPM and PERT. Both Labor and Foreman workers experienced an insignificant increase in manhour values, while Crane Operator workers experienced an insignificant decrease in manhour values.

In this sub-chapter, manpower and manhour efficiency calculations are carried out by comparing the existing work condition 4 data which has been processed with the calculation results resulting from the application of the CPM and PERT methods. Calculation of manpower efficiency and manhour efficiency values is carried out using equations (11) and (12). An example of a calculation carried out on the type of labor force with the application of CPM, and the same calculation is carried out for each type of labor force as well as for the total labor force and expressed in percentage form:

Table 17. Recapitulation of Manpower and Manhour Efficiency

Labor	Manpower		Manhour	
	CPM	PERT	CPM	PERT
Laborer	-17%	-17%	-1,95%	-1,45%
Crane Operator	0%	0%	12,62%	13,04%
Foreman	-17%	-17%	-1,95%	-1,45%
Total	-14%	-14%	0,13%	0,62%

Source: Researcher

Based on the results of manpower and manhour efficiency calculations listed in Table 17, it shows that after implementing the CPM and PERT methods which resulted in an acceleration of work duration. Overall, the efficiency value decreased by -14% due to an increase or addition in the number of new manpower by 14% of initial allocation. Meanwhile, overall manhour efficiency results in an increase in efficiency value of 0.13% in the application of CPM, and 0.62% in the application of PERT. The manhour efficiency value in the PERT application produces a higher value because the work duration is slightly faster compared to the CPM application. This is in line with research of [3] who said that one of the efforts to accelerate the duration of the project could be achieved by adding additional workforce. So the negative efficiency value produced in the manpower calculation is an effort to speed up the duration of work in accordance with the plan for implementing CPM and PERT which has been carried out in Condition 4 of the loading and unloading process of the MV Future Ocean 14,514 DWT ship at Semayang Port, Balikpapan.

CONCLUSION

The conclusions of this research are: 1) The S-curve produced in the four conditions of the loading and unloading process of the MV Future Ocean 14,514 DWT ship shows that the growth in the weight of work duration per hour in Condition 4 has better consistency, as seen in the curve line which does not have much fluctuation. 2) Application of the critical path method and program evaluation and review technique can speed up the duration of the loading and unloading process for the MV Future Ocean 14,514 DWT Condition 4 vessel by 181 minutes on CPM and 183.33 minutes on PERT with a probability of success on time of 82.21%. 3) The application of the CPM and PERT methods overall manpower experienced a decrease in the same efficiency value, namely -14%. The manhour efficiency value in the PERT application results in an increase in more efficient value, namely 0.62%, while the CPM application produces an efficiency value of 0.13%.

REFERENCES

[1] D. Santika, S. P. Lestari and B. Barlian, "Analisis Penjadwalan Proyek Dengan Metode CPM PERT (Studi Kasus Pada Proyek Rumah Makan Kampung Swasana Kota Tasikmalaya)," vol. 2, pp. 599-610, 2022.

[2] Abdurrasyid, Luqman, A. Haris and Indrianto, "Implementasi Metode PERT dan CPM pada Sistem," vol. 5, pp. 28-36, 2019.

[3] M. F. M. Djau, T. T. Arsjad and R. L. Inkiriwang, "Percepatan Pelaksanaan Proyek dengan Penambahan Tenaga Kerja pada Pembangunan Ruko di Jalan Bukit Moria, Tikala Baru," *Jurnal Sipil Statik Vol. 9, No. 4, Juli 2021,* vol. 9, pp. 709-716, 2021.

[4] M. M. Cynthia, H. Cipta and S. R. Lubis, "Penerapan Critical Path Method (CPM) dalam Menganalisis Manajemen Waktu pada Perencanaan Iklan GMS Digital Marketing," *Lebesgue: Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika Vol. 5 No. 2, Agustus 2024,* vol. 5, pp. 820-834, 2024.

[5] Ningrat A, Tahir A. Optimizing Container Crane Performance: Enhancing Loading and Unloading Productivity at PT. Kaltim Kariangau Terminal. *Indonesian Journal of Maritime Technology*. 2024 Dec 16;2(2).

[6] F. A. Junaidi, S. N. Sari and O. H. Ardian, "Analisa Rancangan Anggaran Biaya dan Penjadwalan pada Pembangunan Dinding Penahan Tanah," *STORAGE-Jurnal Ilmiah Teknik dan Ilmu Komputer, Vol. 2 No. 3, Agustus 2023, 77-86,* vol. 2, pp. 77-86, 2023.

[7] A. Nalhadi and N. Suntana, "Analisa Infrastruktur Desa Sukaci-Baros dengan Metode Critical Path Method (CPM)," *Jurnal Sistem dan Manajemen Industri Vol. 1 No. 1, Juli 2017,* vol. 1, pp. 35-42, 2017.

[8] I. Widiasanti, G. Alpinas, M. I. N. Rizqy and J. Ryzki, "Analisis Koefisien Tenaga Kerja Konstruksi Pekerjaan Pelat dan Balok Bertulang pada Bangunan Tingkat Tinggi," *Jurnal IKRA-ITH TEKNOLOGI Vol 5 No 2 Juli 2021,* vol. 5, pp. 91-98, 2021.

[9] P. Maranresy, B. F. Sompie and P. Pratasis, "Sistem Pengendalian Waktu pada Pekerjaan Konstruksi Jalan Raya dengan Menggunakan Metode CPM," *Jurnal Sipil Statik Vol. 3 No. 1 Januari 2015,* vol. 3, pp. 8-15, 2015.

[10] C. S. Budiono, N. B. Sukmabuana, F. K. Rahmawati and S. A. Wibisono, "Analisis Efisiensi Manhours pada Pemeliharaan Structural Interity Program Pesawat C-130 Hercules Menggunakan Metode Critical Path," *Vortex Vol. 5, No. 2, Juli 2024,* vol. 5, pp. 73-80, 2024.

[11] R. G. Sanjaya and H. C. Palit, "Peningkatan Efisiensi Manpower Berdasarkan Prinsip Shoujin di Area Produksi Head Lamp PT Astra Otoparts Divisi Adiwira Plastik," *Jurnal Titra, Vol. 1, No. 2, Juli 2013,* vol. 1, pp. 97-102, 2013.

[12] D. Sulistia and I. D. Agustina, "PENJADWALAN PROYEK DENGAN KURVA-S PADA PEMBANGUNAN PERUMAHAN DI KOTA BEKASI," *Jurnal Al Ulum LPPM Universitas Al Washliyah Medan Vol. 11 No. 2 Tahun 2023,* vol. 11, pp. 100-106, 2023.

[13] J. F. Hair, J. J. Risher, M. Sarstedt and C. M. Ringle, "When to use and how to report the results of PLS-SEM," *European Business Review, 31(1), 2–24,* vol. 31, pp. 2-24, 2019.

[14] R. A. Husna, N. F. Ilmiyah and N. C. Resti, "Implementasi CPM dan PERT dalam Memprediksi Durasi serta Biaya Pembangunan Musala Al-Ikhlas di Kotawaringin Barat," vol. 5, pp. 97-109, 2022.