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Network Planning Analysis Using CPM and PERT Methods on Optimization of Time and Cost

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Abstract: The shipbuilding industry is the most important industry to support sea transportation in the context of maritime development. As a company engaged in shipping, the function of the shipyard is as a place for shipbuilding, ship repair, and ship maintenance. Ship repair is a process of repairing or replacing ship materials that cannot be used to avoid risks that occur in the sea when the ship sails. In the implementation of project activities, the company must understand the right network so that there are no problems scheduling, planning and controlling project activities. This study aims to solve the problems faced by the company, is the delay in completion time. The data used is secondary data related to the sequence and relationship of activities, execution time, and cost budget plan (RAB). This study uses CPM and PERT methods to determine the optimal turn around time using critical path and probability concepts. The results of the CPM and PERT methods are activities on the critical path with an optimal duration of 98 days. The crashing method is to reduce the duration to 72 days with savings of Rp. 16,351,708. if the project implementer does not crash, the penalty that must be paid is Rp. 3,072,963,905.

Keywords: Crashing Method, Network Planning, Optimal Duration

INTRODUCTION

Ship repair is the process of repairing or replacing ship materials that are no longer suitable for use and do not meet the size of the feasibility classification. By making repairs, the ship that will sail later must be in a decent state to avoid the risks that exist in the sea while the voyage is in progress (Luhur P et al., 2017). Therefore, a competent company can complete its work on time in accordance with what has been agreed by each the implementers. But we know that controlling a project is not easy because the larger the size of the project, the more complicated the project activity. It is inevitable that in every work implementation has various possibilities that can affect the implementation so that it experiences delays in implementation and late completion time. The failure of a project is caused by the lack of planning, scheduling and management of project activities so that the activities on the project do not run effectively and have an impact on decreasing the quality of the work (Lokajaya, 2019). In avoiding the failure of a project, good planning, effective scheduling and efficient control are needed (Sari et al., 2018). With applied mathematics being universal, operations research science is a management tool that combines science, mathematics and logic for optimal problem solving and begins with compiling models of problem systems found to be both deterministic and probabilistic in real life (Meflinda & Mahyarni, 2011). To schedule and control project activities effectively, using the CPM (critical path method), PERT (project evaluation review and techniqie) methods to design network planning and crashing methods to optimize time and costs (Prawira, 2020).

The purpose of this study is to plan and schedule effectively project activities, in order to solve the problem, is the late completion time of the ship repair project TK Aek Sigala gala at PT DNC by using CPM and PERT methods to design network planning. With effective network planning, a more planned work schedule can optimize time and costs to be more optimal as expected by using the crashing method.

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METHOD

Planning and scheduling activities requires a method called network planning. Network Planning is a process analysis by describing a work diagram, which can estimate and determine the path of activity that requires precise control (Meflinda & Mahyarni, 2011).The CPM and PERT are methods used to design network planning.

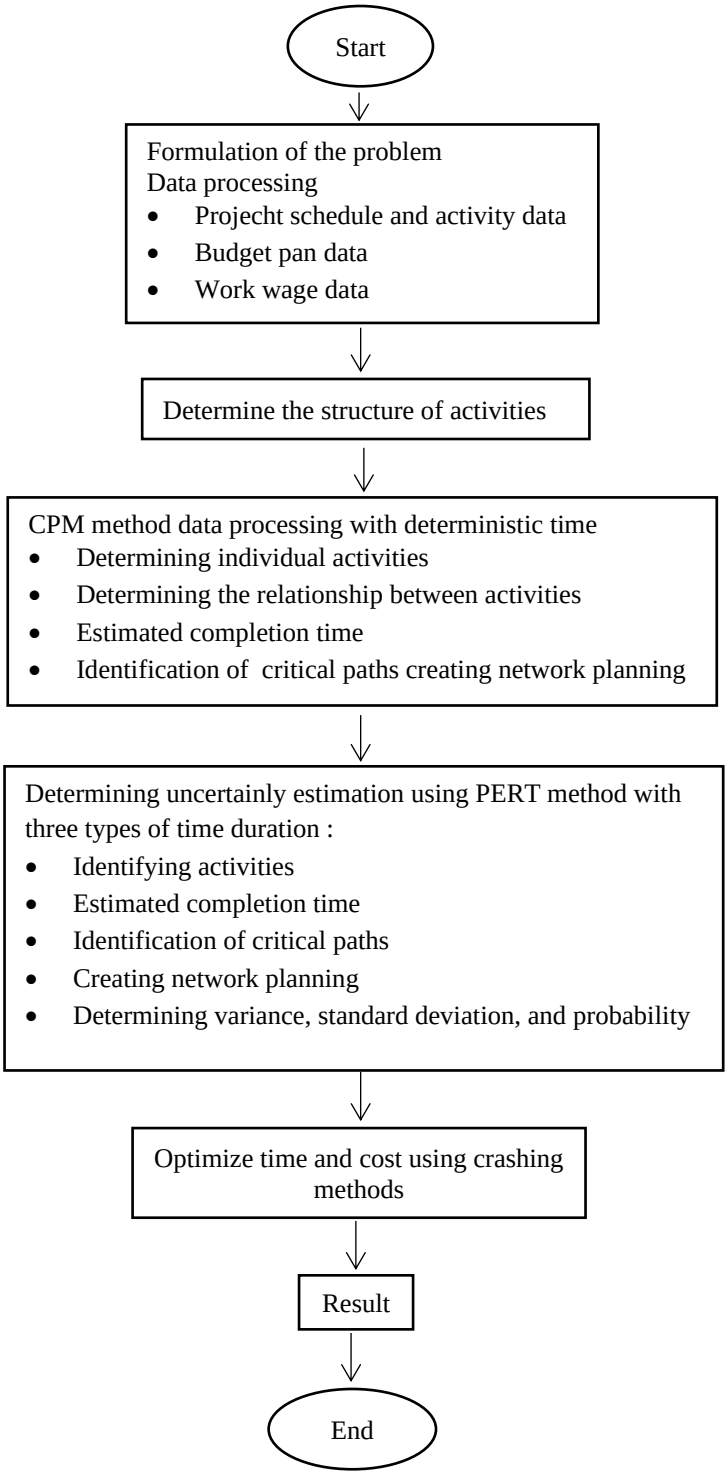

Fig 1. Design of Research

Scheduling CPM Method

CPM or critical path method is a method that can be used to plan and manage a project using a time activity flowchart diagram in completing a project and the connectedness between its resources has been

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determined with certainty (Anenda, 2020). The critical path on the CPM method can be calculated by the total duration of the project. A critical path is a sequence of critical activities that determines the timeframe for project completion. The calculation model of the CPM method is:

- Forward Pass Calculation
  Advanced calculation is a method the one inuse to determining the critical path starting from Node first on a diagram Activity pipeline project.

$$ES = \max\ (EF\ previously) \quad (1)$$
$$EF = ES + duration \quad (2)$$

- Backward Pass
  Countdown is a method which can be used to Define the critical path of the endpoint deep Diagram Activity pipeline project.

$$LS = LF - duration \quad (3)$$
$$LF = \min\ (LS\ next\ activity) \quad (4)$$

Scheduling PERT Method

PERT or Project Evaluation and Review Technique is a management science to plan and manage a project in calculating the estimated time needed (Yuliarty et al., 2021). In analyzing PERT also serves to negotiate fellow customers with parties related to the implementation of the (John M. Nicholas, 2008). Estimates on PERT use time ranges that indicate uncertainty related to estimated activity times. This estimate can calculate the expected time (te) in completing project work (Soeharto, 1999).

$$te = \frac{ta+4tm+tb}{6} \quad (7)$$

In addition to calculating the expected time, the PERT method can calculate the risk of the project with the opportunity that the project can be completed sooner or according to the agreed upon.

$$\sigma^2 = \left[\frac{tb-ta}{6}\right]^2 \quad (8)$$
$$v(te) = S^2 = \left[\left(\frac{1}{6}\right)(tb - ta)\right]^2 \quad (9)$$
$$z = \frac{T(d)-T(e)}{S} \quad (10)$$

Optimization With *Crashing* Method

The crashing method is the process of shortening the duration of project completion which is carried out in a structured and logical manner from all project activities (Yuliarty et al., 2021). The crashing method aims to optimize the duration of the activity at cost efficiently. In the crashing method, there is a Time Cost Trade Off or time exchange and the cost is a reduction in working hours by adding efficiency costs. Crashing methods generally have a significant impact on project delays due to lack of time on the critical path resulting in less activity on the critical path (Anenda, 2020). In the crashing method or acceleration method, there is a cost slope. Cost slope is the cost when there is an acceleration of time in the completion of a project.

RESULT

Analyzing critical pathways with the CPM method

Preparation of critical paths using the CPM method begins with creating a flow chart of activities, then determining the critical path that is the basis for project planning and management (Saputra et al., 2017). The steps to schedule and control a project with the CPM method are:

1) Making a schedule of activities for TK. Aek Sigala gala

Table 1. Sequence and Relationship of Ship Repair Project Tk Aek Sigala Activities

No	Code	Activities	Duration (Days)	Prodecessor	Successor
		Start		-	-
1	A	Preparatory work - socialization - lighting and water - mobilization and demobilization - work equipment and materials	7 days	-	B,C,D
2	B	High bow repair	8 days	A	G
3	C	Bottom improvements	6 days	A	F

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3	D	Bulkhead repair	6 days	A	E
4	E	Right & left hull repair	7 days	D	G
5	F	Deck repair	6 days	C	G
6	G	Repair of the US propeller / stream tube	8 days	B,E,F	H,I
7	H	Wheelhouse repair	5 days	G	J
8	I	Bathroom repair	5 days	G	K
9	J	Steering skek repair	4 days	H	L
10	K	Daily tank plate installation	5 days	I	L
11	L	Installation of machine bench plate	4 days	J,K	M,N
12	M	Bullwark improvements	8 days	L	O
13	N	Ramp door repair	7 days	L	O
14	O	Power steering installation	18 days	M,N	P,Q
15	P	Auxiliary engine installation	16 days	O	R
16	Q	Electrical installation	14 days	O	R
17	R	Painting	14 days	P,Q	*End*
		End	-	-	-

2) Scheduling with CPM method and Network Planning

Table 2. Critical Path Calculation with Critical Path Method

No	**Activity Code**	**Duration (days)**	**ES *(earlliest start)***	**EF *(earliest finish)***	**LS *(Latest start)***	**LF *(latest finish)***	***Slack* / TF**	**Critical Path**
1	A	7	0	7	0	7	0	Yes
2	B	8	7	15	12	20	5	No
3	C	6	7	13	8	14	1	No
4	D	6	7	14	7	13	0	Yes
5	E	7	13	19	13	20	0	Yes
6	F	6	13	20	14	20	1	Not
7	G	8	20	28	20	28	0	Yes
8	H	5	28	33	29	34	1	No
9	I	5	28	33	28	33	0	Yes
10	J	4	33	37	34	38	1	Not
11	K	5	33	38	33	38	0	Yes
12	L	4	38	42	38	42	0	Yes
13	M	8	42	50	42	50	0	Yes
14	N	7	42	50	43	50	1	Not
15	O	18	50	68	50	68	0	Yes
16	P	16	68	84	68	84	0	Yes
17	Q	14	68	84	70	84	2	Not
18	R	14	98	98	84	98	0	Yes

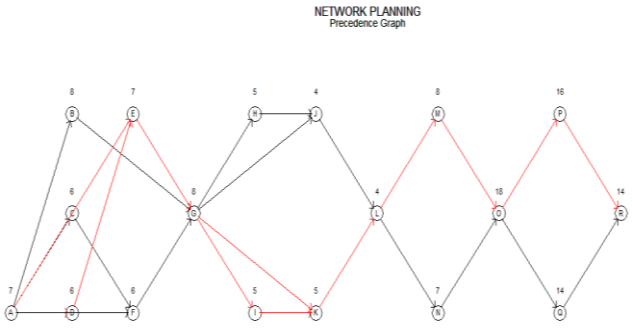

Fig2. Network Planning with CPM Method

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In figure 1 Above with do forward and countdown calculations, schedule for the implementation of repair TK. Aek Sigala gala is as large as 98 days where its critical trajectory Retrieved : A – D – E – G – I – K – L – M – O – P – R

Calculating the estimated completion time of the ship repair project TK Aek Sigala-gala with PERT method (Program Evaluation Review and Technique)

A project requires uncertain calculations to predict the completion time so as to avoid late project implementation which is influenced by its factors. The PERT method is performed by calculating the estimated duration of each activity, with optimistic duration (ta), realistic duration (tm), and pessimistic duration (tb).

Table 3. Value Recapitulation Te and Variance

Kode	Activity	Duration				
		ta	tm	tb	te	σ^2
A	Preparatory work	6	7	8	7	0,111
B	High bow repair	7	8	9	8	0,111
C	Bottom inprovements	5	6	7	6	0,111
D	Bulkhead repair	5	6	7	6	0,111
E	Right & left hull repair	6	7	8	7	0,111
F	Deck repair	5	6	7	6	0,111
G	Repair of the US Propeller / stream tube	7	8	9	8	0,111
H	Wheel house repair	4	5	6	5	0,111
I	Bathroom repair	4	5	6	5	0,111
J	Steering skek repair	3	4	5	4	0,111
K	Daily tank plat installation	4	5	6	5	0,111
L	Installation of machine bench plat	3	4	5	4	0,111
M	Bullwark improvements	7	8	9	8	0,111
N	Ramp door repair	6	7	8	7	0,111
O	Power steering installation	16	18	20	18	0,444
P	Auxiliary engine installation	14	16	18	16	0,444
Q	Electrical installation	12	14	16	14	0,444
R	*Painting*	12	14	16	14	0,444

Optimistic duration time (ta), Most Likely Time (tm), and Pesimistic Duration Time (tb) can affect the expected duration of completion of work (te). By combining ta, tm and tb is performed to determine sum that true.

Determining Probability Completion of the Ship Repair Project TK Aek Sigala-gala Using the PERT–CPM Method

From the specified critical path, the *Te* value is 98 days. To calculate the standard deviation value of the critical path, namely:

$$S = \sqrt{\sum(\sigma^2 \; of \; critical \; path)}$$

$$S = \sqrt{2,22}$$

$$S = 1,489$$

Te and *S* values used to reduce the presence of risk Settlement a project, z value inuse to determinants chance time in resolving project with time the Forecast. From forecasts Td value is 96 days. Obtained *z* value calculated by the way:

$$z = \frac{T(d) - T(e)}{S}$$

$$z = \frac{96 - 98}{1,489}$$

$$z = -\frac{2}{1,489}$$

$$z = -1,343$$

Based on the calculation of the probability value obtained z value of - 1.343. from the z table the normal distribution is by 0.0918. The value if concentrated will be 9.18%. The probability of the project completed in 96

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days is approximately 9.18%. The probability of the project being completed is below 50%. Then it can be seen that the project implementer will experience delays in the completion of the project.

Optimizing Time and Cost Using *Crashing* Methods

In this study, the crashing method uses alternative additions of labor. so that with do additional labor, get create activity from the project can be completed quickly. Adding manpower according to the needs of project implementers Field with The cost per day is Rp. 100.000 / person

Table 4. Recapitulation values of CD, CC, and CS

No	Activity Code	*Normal Duration*	*Normal cost*	*Crash duration*	*Crash Cost*	*Cost Slope*
1	A	7	5.000.000	4	5.800.000	266.666,66
2	B	8	7.231.500	6	7.831.500	300.000
3	C	6	81.936.000	5	82.436.000	500.000
4	D	6	40.946.500	5	41.446.500	950.000
5	E	7	31.246.000	5	31.746.000	250.000
6	F	6	68.315.000	5	68.815.000	500.000
7	G	8	21.756.000	6	22.356.000	300.000
8	H	5	4.905.000	3	5.505.000	300.000
9	I	5	9.418.000	3	9.418.000	300.000
10	J	4	16.900.000	3	17.200.000	300.000
11	K	5	1.772.000	4	2.172.000	400.000
12	L	4	7.087.000	3	7.387.000	300.000
13	M	8	11.077.000	6	11.677.000	300.000
14	N	7	42.102.800	6	42.702.800	600.000
15	O	18	32.241.824	14	33.641.824	350.000
16	P	16	47.357.000	11	48.457.000	220.000
17	Q	14	30.611.706	12	31.511.706	180.000
18	R	14	25.100.000	9	26.300.000	600.000
Sum			485.403.330		496.403.330	

Time Cost Trade Off Analysis

Reduction stage with maximum *crashing* duration
Cost slope = Rp. 220.000/day
Time Normal = 16 days
Time crashing = 11 days
Total crashing = 5 days
Total project duration = 98 - 5 days = 93 days

Direct Costs $= normal\ direct\ costs + cost\ slope$
$= Rp.485.403.330 + (5\ x\ 220.000)$
$= Rp.486.503.330$

Indirect costs $= \frac{direct\ costs}{normal\ duration}\ x\ crashing\ duration$
$= \frac{Rp.73.317.380}{98}\ x\ 93$
$= Rp.69.576.697{,}34$

Total costs $= direct\ costs + indirect\ costs$
$= Rp.486.503.330 + 69.576.697{,}34$
$= Rp.556.080.027{,}34$

DISCUSSION

Based on data processing and the results of analysis and discussions on the ship repair project TK Sigala gala, the critical path obtained by the CPM and PERT methods is the same, is A – D – E – G – I – K – L – M – O – P – R with a duration of 98 days. And for the optimal crashing process is 72 days with the minimum total cost Rp. 540.219.158. From Fahrian's research, is analyzing the comparison of project scheduling with PDM (predence diagram method) and CPM (critical path method) method to islamic school building projects, based on scheduling carried out the PDM method is more effective because in the project there are overlapping activities.

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CONCLUSION

Some of the problems faced by the implementers of the ship repair project TK Aek Sigala gala is a delay in completion activities, with the postponement of project activities, the project experiences delays in project completion which is influenced by several factors. Therefore, to minimize the occurrence of delays in completion, the right planning, scheduling, and control process is carried out. With the CPM and PERT methods used by researchers, there are several activities that are on the critical path, where on that path the project implementer strives to ensure that there is no time allowance in implementation, namely A – D – E – G – I – K – L – M – O – P – R activities with an optimal duration of 98 days. From the agreed duration of the work contract, which is 96 days, there has been an opportunity to complete the project by 9.18%. It can be seen that the project has the possibility of experiencing delays in completing the project. In this case, it is certainly necessary to do an appropriate way so as not to miss too far from the agreed employment contract agreement. With the crashing method, an alternative is obtained, namely by crashing is 72 days, which is able to shorten the time by 26 days from the duration of 98 days. This reduction saves costs of Rp. 16,351,708 with an additional workforce of 22 people. If the project implementer does not use the crashing method, it seen from the completion time of 101 days, the delay is 4 days from the agreed contract. The implementers can pay a penalty of Rp. 3,072,963. When compared, project implementers can choose crashing with savings of Rp. 16,351,708 and saving time by 26 days, provided that implementers add manpower and do not give time leeway on critical path than having to pay a penalty of Rp. Rp. 3,072,963,905.

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