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OPTIMIZATION OF AIR CENTER DEVELOPMENT PROJECTS IMPLEMENTATION USING CRITICAL PATH METHOD AND PROJECT EVALUATION REVIEW TECHNIQUE IN PERUM PERURI'S NON MONEY PRODUCTION DIVISION

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The case study in this research is the Perum Peruri Non-Money Production Division Air Center Development project. The analysis method used in this research is the Critical Path Method (CPM) and Project Evaluation Review Technique (PERT). This analysis method is used to analyze the optimal time and optimal cost of the project which previously took 180 days and cost Rp. 7,939,812,640,-, in order to find out possible accelerate time and the optimal cost of the project. The acceleration method achieved by increasing the working time (overtime hours) for the project workers and also by increasing the number of workers on the project. The results obtained are as follow; there are 3 project paths that occur. One critical path with a project completion time of 180 days. By using the Project Evaluation Review Technique (PERT) method with a Td value of 187 days the probability of project completion is 99.18%, The optimal project time is 168 days which obtained through overtime for 2 hours / day and by using the Project Evaluation Review Technique (PERT) method with a value of Td = 176 days, the probability of project completion is 99.20% and the optimal cost of the project is Rp. 7,649,700,010,- with an increase in costs of 0.03% with a value of Rp. 2.362.000,-

Keywords: Optimization, Critical Path Methode (CPM), Project Evaluation Review Technique (PERT)

1. INTRODUCTION

This air center construction project has a budget of Rp.7,939,812,640,-, in the initial planning process this project was planned to be completed within 180 working days with the provision of 7 working days, but management wants to cut the project duration in order the project is completed faster so that it does not interfere the ongoing production process and the authors also examines whether the order of project work execution is correct? Of course this will have an effect on increasing the cost of completing the project, therefore the authors will conduct research by finding the optimal project time and optimal project cost by using CPM (Critical Path Method) and PERT (Project Evaluation Review Technique). With these methods the authors will have optimal outputs, namely optimal time and optimal cost so that the project is expected to be completed faster and at a cost that can be reached by the company.

2. LITERATURE REVIEW

2.1. Project Definition

*Projects can be defined as a series of related tasks directed toward a major output. In some firms a project organization is developed to make sure existing programs continue to run smoothly on a day-to-day basis while new projects are successfully completed (*Heizer and Render,2017).

2.2. Project Manajement

Project management is also knowledge, skills, tools and techniques in project activities so that project requirements and needs are met. Processes in project management can be grouped into 5 groups, namely initiating process, planning process, executing process, controlling process and closing process (Dimyati, 2014).

2.3. *Critical Path Methode (CPM)*

The CPM method (Critical Path method) is a critical path method developed in the 1950s to help managers schedule, monitor, and control large and complex projects (Heizer and Render, 2011). CPM is a project management model that prioritizes cost as the object being analyzed (Siswanto, 2007). Critical Path Method (CPM), is a network-based method that uses a linear balance of time and cost (Schroeder, 2006)

2.4. *Network Planning*

Network Planning is a project planning and control that describes the dependency relationship between each job described in the Network Diagram (Dimyati, 2014)

2.5. *Activity On Node (AON)*

One of the project networks is the AON network or activity on node (AON) In the AON approach, circles or nodes indicate activities, arrows identify how the activities are related and the sequence of these activities (Nurhayati, 2010)

2.6. Slack Time dan Jalur Kritis

Slack time is the free time that each activity has to be able to be postponed without causing delays in the overall project (Dimyati, 2014). Mathematically, the slack time can be formulated as follows: **Slack = LS – ES or Slack = LF – EF**. Activities with slack = 0 are called critical activities and are on the critical path. The critical path is the path with the longest time through the network. Usually a critical path consists of jobs that cannot be delayed when they are executed. Critical path analysis helps determine the project execution schedule. Determination of the completion time of a project can be done through the forward pass and backward pass processes. ES (early start) and EF (early finish) are determined during the forward pass. LS (latest start) and LF (latest finish) are determined during the backward pass.

1. ES (early start) and EF (early finish) during the forward pass. How to search ES and EF by calculating from the initial activity to
the end is Haryadi Sarjono (2010)
ES = ES of predecessor activity + Time of predecessor activity
EF = ES of the activity + Time of the activity

2. LS (latest start) and LF (latest finish) are determined during the backward pass. The way to find LS and LF is to count backwards from the start of the final activity to the initial activity (Haryadi Sarjono, 2010)
LS = LS of the activity after – The time of the activity
LF = LS of the activity + Time of the activity

2.7. Project Evaluation Review Technique (PERT)

PERT (Program Evaluation and Review Technique) is a project management technique that uses three time estimates for each activity, PERT was developed in 1958 by Booz, Allen and Hamilton for the United States Navy (Dimyati, 2014). PERT is a project scheduling method based on a network that requires 3 time estimates for each activity, namely: optimistic, most likely, and pessimistic (Schroeder, 1996)

The explanations for the 3 (three) estimation times are:

1. Optimistic time [a]
   Optimistic time is the shortest possible time for an event to occur. The time required by an activity if everything goes according to plan (Nurhayati, 2010)
2. Pessimistic time [b]
   Pessimistic time is the longest time it takes for an event to complete a job. The time required for an activity assuming the existing conditions is very unexpected (Nurhayati, 2010)
3. Realistic time (most likely time) [m]
   Realistic time is the most appropriate time for the completion of a work activity in the PERT network, the estimate of the time required to complete an activity that is the most realistic to be completed (Nurhayati, 2010)

2.8. Crashing Methode

Crashing the project or accelerating the execution of the work means shorten the life (project implementation). How long or the duration of the project completion is equal to the amount of time that exists on a critical path (Critical Path) (Dimyati, 2014).

3. METHODOLOGY

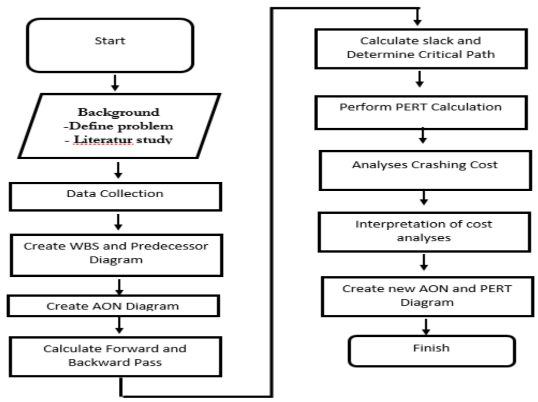
3.1. Types of research

The type used in this research is quantitative research. This quantitative research is used to answer problems through careful measurement techniques of certain variables in order to produce conclusions that can be generalized regardless of the context of time and situation and the type of data used is a quantitative data. The quantitative data itself is data in the form of numbers, or quantitative data that is scored (scoring). The data used in this study include: CBP (Cost Budget Plan), Activity plan, BQ (Bill of Quantities), TOR (Terms of Reference)

3.2. Population and sampel

In this study the population and sample are single because there is no similar project, the population and sample from this research is the Water Center Development Project in the Non-Cash Production Division of Perum Peruri.

3.3. Research Model



3.4. Type of Data

The data used in this study are primary data and secondary data. Primary data obtained from the results of surveys, observations and interviews. The secondary data from this research is the data on the construction of the Perum Peruri B Perum Peruri Air Center Money Production Division.

3.5. Analyses Method

1. Create Predecessor and Sucessor diagrams

   Predecessor and Sucessor diagrams are construct to show the sequence of work, this diagram contains the activities in the project and shows the sequence of work carried out, this diagram shows the relationship between which activities are the predecessors of the activity (Predecessor) and which activity is the follower (Successor).)
2. AON Diagram

   By using the AON diagram, the information obtained is more complete because starting from the name of the activity, the duration of the project, the value of Early Start, Early Finish, Latest Start and Latest finish are in 1 node, making it easier to process the information in the node.
3. Calculation of CPM

   After making network planning using the AON (Activity On Node) method, the author makes a table of Early Start, Early Finish, Latest Start and Latest finish values and calculates the value of float / slack with the formula LS - ES or LF - EF, then determines the points which is critical by looking at the results of the float / slack calculation, activities that have float / slack = 0 will be a critical point and if connected will be the longest path and become the project's critical path.
4. Project Evaluation Review Technique (PERT)

   making PERT (Program Evaluation and Review Technique) analysis, the author will determine the duration of the project using the three times estimated method which consists of the project's optical time (a), the project's pessimistic time (b) and the project's realistic time (m).
5. Optimization Analysis

   Optimization analysis is carried out to find the optimal time and optimal cost of the project.

4. RESULT AND DISCUSSION

4.1. Data Analyses

4.2.1. Predecessor Diagram

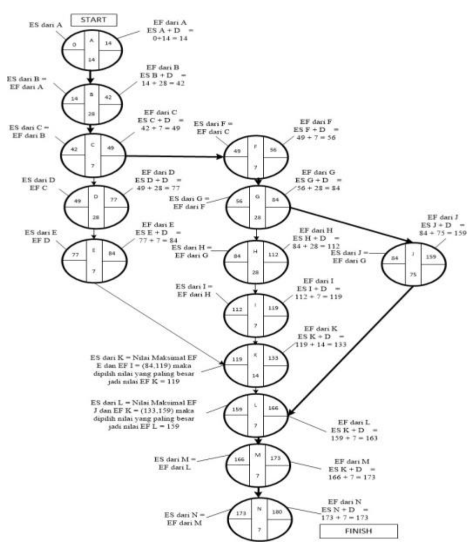
Predecessor diagrams are used to show the relationship between activities consisting of Predecessor (Predecessor Activities) and Successor activities (Follower Activities), Following are the Predecessors of this project:

Table Predecessor

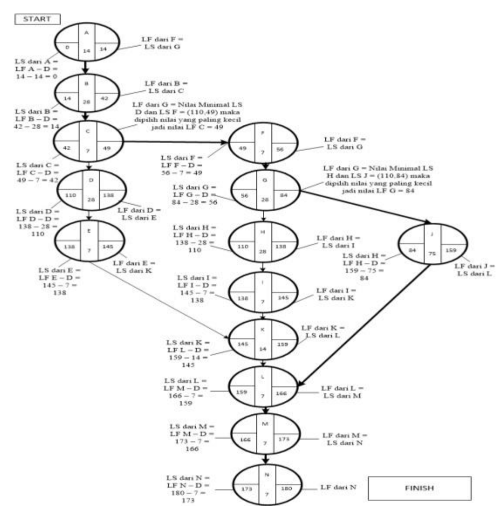
Codes	Activities	Predecessor	Duration (Days)
A	Conduct Technical Studies	-	14
B	Detailed Engineering and Design (DED)	A	28
C	Revision and Approval	B	7
D	Compressor Supply	C	28
E	Delivery	D	7
F	Preparatory work	C	7
G	Building Works	F	19
H	Architectural Jobs	G	28
I	Drainage Works	H	7
J	Piping Job	G	70
K	Electrical Works	E;I	14
L	Mechanical Work	J;K	7
M	Finishing Work	L	7
N	Closing Job	M	7
TOTAL DURATION			264

4.2.2. Critical Path Analysis

Froward Pass Analysis



Backward Pass Analysis



4.2.3. Critical Path Analyses

Table Slack and Critical Path

Code	Activities	Predecessor	time	ES	EF	LS	LF	S	Adj.
A	Conduct Technical Studies	-	14	0	14	0	14	0	Critical
B	Detailed Engineering and Design (DED)	A	28	14	42	14	42	0	Critical
C	Revision and Approval	B	7	42	49	42	49	0	Critical
D	Compressor Supply	C	28	49	77	110	138	61	
E	Delivery	D	7	77	84	138	145	61	
F	Preparatory work	C	7	49	56	49	56	0	Critical
G	Building Works	F	28	56	84	56	84	0	Critical
H	Architectural Jobs	G	28	84	112	110	138	26	
I	Drainage Works	H	7	112	119	138	145	26	
J	Piping Job	G	75	84	159	84	159	0	Critical
K	Electrical Works	E;I	14	119	133	145	159	26	
L	Mechanical Work	J;K	7	159	166	159	166	0	Critical
M	Finishing Work	L	7	166	173	166	173	0	Critical
N	Closing Job	M	7	173	180	173	180	0	Critical

4.2.4. Calculation of PERT in Normal Time

Table Three Time Estimate in Normal Duration

code	Activities	Pred.	a	m	b	mean	Varian	Deviation Standard
A	Conduct Technical Studies	-	10	14	18	14	1.78	1.33
B	Detailed Engineering and Design (DED)	A	25	28	30	28	0.69	0.83
C	Revision and Approval	B	6	7	10	7	0.44	0.67
D	Compressor Supply	C	25	28	30	28	0.69	0.83
E	Delivery	D	5	7	9	7	0.44	0.67
F	Preparatory work	C	5	7	9	7	0.44	0.67
G	Building Works	F	25	28	32	28	1.36	1.17

H	Architectural Jobs	G	25	28	33	28	1.78	1.33
I	Drainage Works	H	5	7	9	7	0.44	0.67
J	Piping Job	G	70	75	79	75	2.25	1.50
K	Electrical Works	E;I	7	14	19	14	4.00	2.00
L	Mechanical Work	J;K	6	7	9	7	0.25	0.50
M	Finishing Work	L	5	7	11	7	1.00	1.00
N	Closing Job	M	5	7	8	7	0.25	0.50

PERT Analyses calculation
Critical Path = A-B-C-F-G-J-L-M-N

1. ∑TE = Cummulatif duration of Te in the critical path
   = 180
2. ∑ Vt = Varians total (Vt) at critical path
   = 8.47
3. ∑ St = Total deviation standard at critical path / $\sqrt{\sum Vt}$
   = 2.91
4. Td = Schedule target
   = 187 Hari
5. Calculation of project completion probability

$$z = \frac{Td - Te}{St}$$

z = 2.40

With value of z = 2.40 it can be obtained 0,9918, so that percentage of project completion in 187 days is 99,18 %.

4.2.5.Crashing Analysis

Crashing with overtime 2 hours per day

Table of normal costs and project accelerated costs with the overtime method of 2 hours per day

codes	Activities	Normal Duration	Accelerated	Normal Cost	Accelerated Cost
F	Preparatory work	7	6	Rp 5,060,000	Rp 5,392,500
G	Building Works	28	23	Rp 39,200,000	Rp 40,206,250
J	Piping Job	75	63	Rp 146,250,000	Rp 148,612,500
L	Mechanical Work	7	6	Rp 5,600,000	Rp 5,775,000
M	Finishing Work	7	6	Rp 3,360,000	Rp 3,412,500
N	Closing Job	7	6	Rp 3,500,000	Rp 3,609,375
TOTAL				Rp. 273.390.000	Rp. 278.460.625

Table of Slope Each Activity

codes	Activities	Normal Duration	Accelerate duration	Slope
F	Preparatory work	7	6	Rp 237,500
G	Building Works	28	23	Rp 201,250
J	Piping Job	75	63	Rp 196,875
L	Mechanical Work	7	6	Rp 175,000
M	Finishing Work	7	6	Rp 37,500
N	Closing Job	7	6	Rp 109,375

Table of Additional Cost Calculation

Codes	Activities	Normal Duration	Accelerate Duration	Additional Cost	Total Cost after accelerate
M	Finishing Work	7	6	Rp 37,500	Rp 7,939,865,140
N	Closing Job	7	6	Rp 109,375	Rp 7,939,922,015
L	Mechanical Work	7	6	Rp 175,000	Rp 7,939,987,640
G	Building Works	28	23	Rp 1,006,250	Rp 7,940,818,890
F	Preparatory work	7	6	Rp 237,500	Rp 7,940,145,140
J	Piping Job	75	63	Rp 2,362,500	Rp 7,942,175,140

Refering to the calculation above, the optimal project completion time can be obtained with a duration of 168 days by accelerating activity J with overtime for 2 hours. The acceleration has an effect on increasing costs by 0.03% with a value of Rp. 2.362.000,- with a total project completion cost of Rp. 7,942.175.140,- and no new critical path found.

Crashing Analysis* by adding *Manpower

Table of normal costs and accelerated costs of projects with the method of adding labors

Codes	Activities	Number of person after addtion	Normal time	Acc. time	Normal Cost	Accelerate Cost
J	Piping Work	11	75	68	Rp 146,250,000	Rp 153,000,000

Table *of Cost slope from* J Activities

code	Activity	Normal time	Accelerate time	slope
J	Pekerjaan Piping	75	68	Rp 964,286

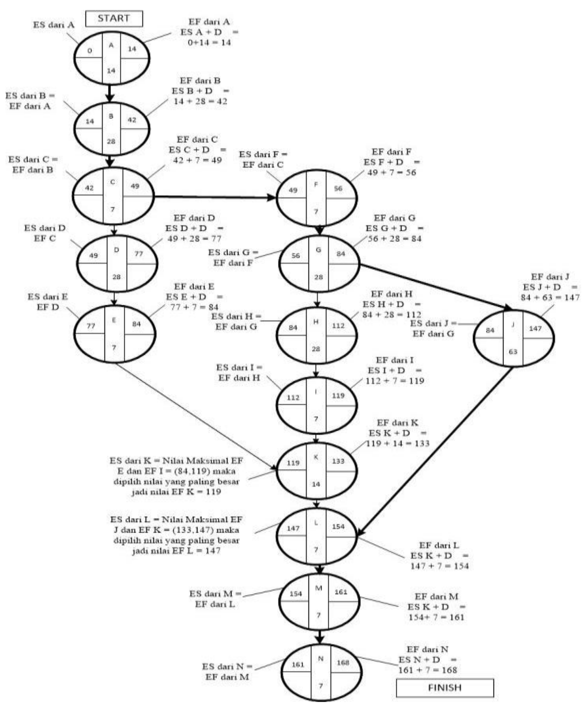
Table of Additional Cost Calcualtion

Codes	Activity	Normal Duration	Acc. Duration	Addition Cost	Total cost after Acceleration
J	P. Piping	75	68	Rp 6,750,000	Rp 7,946,562,640

Referring to the 2 crashing methods, the option to crash with the method of carryout overtime for 2 hours because the additional cost is smaller, 0.03% with a value of Rp. 2.362.000,- compared to adding workers with an additional cost of 0.08% with a value of Rp. 6.750.000,-.

Critical Path Analysis after Crashing

Forward Pass Analysis



Backward Pass Analysis

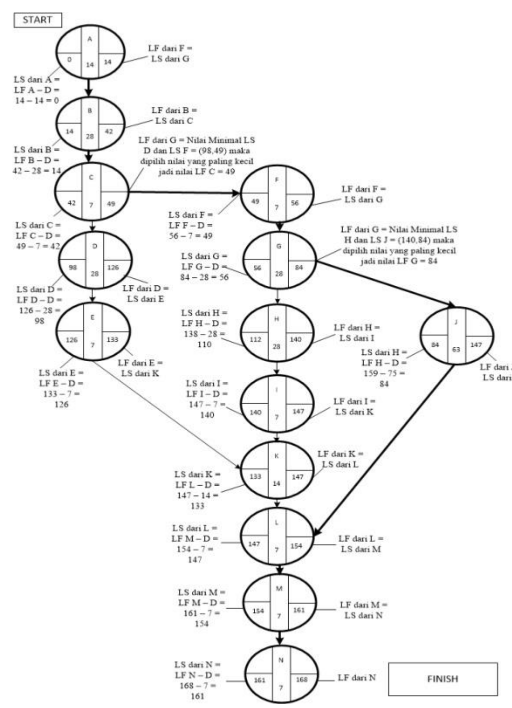


Table of Slack dan Jalur Kritis

Co des	Activities	Prede cessor	time	ES	EF	LS	LF	SL AC K	Adj.
A	Conduct Technical Studies	-	14	0	14	0	14	0	Critical
B	DED	A	28	14	42	14	42	0	Critical
C	Revision and Approval	B	7	42	49	42	49	0	Critical
D	Compressor Supply	C	28	49	77	98	126	49	
E	Delivery	D	7	77	84	126	133	49	
F	Preparatory work	C	7	49	56	49	56	0	Critical
G	Building Works	F	28	56	84	56	84	0	Critical
H	Architectural Jobs	G	28	84	112	112	140	28	
I	Drainage Works	H	7	112	119	138	145	26	
J	Piping Job	G	63	84	147	84	147	0	Critical
K	Electrical Works	E;I	14	119	133	133	147	14	
L	Mechanical Work	J;K	7	147	154	147	154	0	Critical
M	Finishing Work	L	7	154	161	154	161	0	Critical
N	Closing Job	M	7	161	168	161	168	0	Critical

4.2.6. Calculation of PERT Accelerated Time

Table of Three Time Estimate After Crashing

codes	activities	Predecessor	a	m	b	mean	Var.	Std dev.
A	Conduct Technical Studies	-	10	14	18	14	1.78	1.33
B	DED	A	25	28	30	28	0.69	0.83
C	Revision and Approval	B	6	7	10	7	0.44	0.67
D	Compressor Supply	C	25	28	30	28	0.69	0.83
E	Delivery	D	5	7	9	7	0.44	0.67
F	Preparatory work	C	5	7	9	7	0.44	0.67
G	Building Works	F	25	28	32	28	1.36	1.17
H	Architectural Jobs	G	25	28	33	28	1.78	1.33
I	Drainage Works	H	5	7	9	7	0.44	0.67
J	Piping Job	G	57	63	70	63	4.69	2.17
K	Electrical Works	E;I	7	14	19	14	4.00	2.00
L	Mechanical Work	J;K	6	7	9	7	0.25	0.50

M	Finishing Work	L	5	7	11	7	1.00	1.00
N	Closing Job	M	5	7	8	7	0.25	0.50

Calculation of PERT analyses
Critical Node = A-B-C-F-G-J-L-M-N

1. ∑TE = Total duration of Te in critical node
   = 180
2. ∑ Vt = Total Varians (Vt) at critical path
   = 10.92
3. ∑ St = Total Standar deviation at critical path / $\sqrt{\sum Vt}$
   = 3.30
4. Td = Target of Schedule
   = 176 Hari
5. Calculation of the project completion probability value

$$z = \frac{Td - Te}{St}$$

z = 2.42

With a value of z = 2.42, the probability value is 0.9920, so the percentage of project completion time with a duration of 176 days is 99.20%.

CONCLUSION

Based on the predecessor diagram and critical path analysis, 3 work paths were obtained as follows: A-B-C-D-E-K-L-M-N, A-B-C-F-G-H-I-K-L-M-N, A-B-C-F-G-J-L-M-N, based on the results of critical path analysis (CPA) and slack calculations, one critical path was obtained for the project, id.est A-B-C-F-G-J-L-M-N, which obtained a duration of 180 days using the Project Evaluation Review methodTechnique (PERT) with a target date (Td) of 187 days, the z value of 2.40 was obtained based on the normal distribution table z showing a value of 0.9918, so the probability value of project completion for 187 days is 99.18%. The optimal duration of the project is 168 days by accelerating the pipping work activity (J). This result is obtained by carrying out overtime for 2 hours based on critical path analysis (CPA). Accelerating the activity did not creat a new critical. By implementing Project Evaluation Review Technique (PERT) method with a Target date (Td) of 176 days, the z value is 2.42. Based on table z, the normal distribution shows a value of 0.9920, so the probability value of project completion for 187 days is 99.20%. By accelerating the activities of J (Piping Work). The optimal project cost is Rp. 7,942,175,140,-, it means there is an increasing in costs of Rp. 2,362,500,- the percentage increase in costs is 0.03%,

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