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Evaluation of Sport Equipment Procurement Project Scheduling By Implementing Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT)

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ABSTRACT

The success or failure a project is largely determined by the planning and control of the project. This research was conducted on a sports equipment procurement project, especially gym equipment at a national company. The main problem with this project was the delay in completing this project for 33 days due to delays in the shipping department which caused delays in the process of subsequent activities. The purpose of this research is to find the optimal time that can be used to minimize delays in project completion. Optimizing working time is quite important for companies in working on projects to avoid wasting resources and losing the trust of their clients. The methods used in this study are the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). The results showed: the CPM method obtained 15 critical activities with a total duration of 239 days from the previous 306 days and the PERT method obtained 13 critical activities with a total duration of 258 days from the previous 306 days. Of the two methods, there is a difference that is 19 days faster with the CPM method. Thus the CPM method is used further for scheduling this project.

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1. INTRODUCTION

The more advanced human civilization, the larger and more complex the projects carried out using increasingly sophisticated materials, labor and technology [1] [2]. Project management means that all resources in the form of time, money, equipment, human and material capabilities in the construction process are collected as a sequence of activities in a logical framework to form a management system [3]. A project can be defined as an activity carried out within a limited period of time with the aim of allocating certain resources and producing a product or service with well-defined quality standards [4] [5]. Project management has the peculiarity that a manager's working hours are limited by a certain schedule. Project implementation management itself consists of several aspects such as implementation schedule, budget planning, coordination system, project organization, implementation methods, allocating funds to resources and control and monitoring processes during project implementation [6]. Problems in implementation management have a negative impact on project implementation [7].

A common impact is project delays. Project delays usually have a negative impact on builders and contractors. Because the result of delays is not only additional time and costs, but also disputes and arguments about what is to blame and who is to blame [8]. Delaying the completion of the project itself is highly undesirable because it is vital in terms of time and cost and the impact is very detrimental both from the customer and executor side [9] [10]. This research was conducted at a telecommunications and infrastructure contractor company which is only based on experience from various projects so that it is often trapped in the problem of project completion times that are not appropriate and previously agreed upon. This research aims to evaluate the gym equipment procurement project in Jakarta where there is a real time difference with the target time that has been determined for 306 days, but due to many non-technical obstacles such as materials arriving late and unfavorable weather resulting in delays in project completion for 33 days, which means a new project is completed in 339 days.

2. METHODS

In overcoming this problem, researchers made research using the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT).By using the CPM and PERT methods, it can be seen in more detail about the difference in time between the initial conditions and the repair conditions, when the initial conditions often experience delays in processing time from the start of preparatory work to completion and result in poor quality [11]
[12] [13]. Therefore, it must be considered which work should receive more attention because if the work is delayed it will affect the results of other work. CPM is a method designed to optimize project costs where it can be determined when cost and time trade-offs must be made to meet the project completion schedule with the minimum possible costs [14]. PERT is a project management tool that is used to schedule, organize and coordinate parts of the work in a project [15].

Data collection is carried out by observing and recording systematic behavior patterns of subjects (people), objects (things), or events without any questions or communication within the system the individuals studied. Observations were carried out to obtain Time Schedule data. Data Processing and Analysis Methods are [16]:

1. **CPM analysis.** At this stage, a network analysis is carried out using the CPM method. To be able to develop a CPM network, research requires several steps. The steps in compiling a CPM network are: (1) review and identify the project scope, describe it, break it down into activities or groups of activities which are project components,(2) rearrange the components in point 1, to be a link in the appropriate order of the dependency logic, (3) provides an estimated timeframe for each of the activities resulting from the breakdown of the project scope, (4) identify the critical path (critical path) and float on the network. Forward and backward calculations are performed to identify activities that are on the critical path.

2. **PERT analysis.** At this stage a PERT analysis is carried out to determine the duration of each job from the data that has been obtained and to determine the probability of the company achieving the target schedule. To be able to apply the PERT method, research requires the following steps: (1) determine the estimated activity time, (2) determine the standard deviation of project activities, (3) determine the activity variations of project activities, (4) knowing the probability of achieving the schedule target

3. RESULTS AND DISCUSSION

3.1 Description of Activities

The work plan is prepared based on the sequence of activities of all the work in such a way that one job is related to another. The details of its activities are shown in Table 1 below:

Table 1.Project Activities & Duration

No	Activities	Activities Code	Duration	Predecessor
1	Receiving Purchase Order	A	15	
2	Creating Invoice 100%	B	10	A
3	Receive 100%	C	20	B
4	Site Survey	D	10	C
5	Creating Budget	E	20	D
6	Sell in process	F	20	E
7	Shipping process 1 (SP1)	G	40	F
8	Shipping process (SP2)	H	35	F
9	Clearance Process 1 (CP1)	I	10	G
10	Clearance Process (CP2))	J	10	H
11	Arrival at Warehouse 1 (AW1)	K	5	I
11	Arrival at Warehouse 1 (AW1)	K	5	I
12	Arrival at Warehouse 2 (AW2)	L	5	J
13	Equipment Delivered on Site 1 (EDS1)	M	14	K
14	Equipment Delivered on Site 2 (EDS2)	N	10	L
15	Equipment Unloading	O	10	M,N
16	Power Pug Installation	P	7	O
17	Equipment Installation	Q	10	O
18	Repairing defect	R	20	Q
19	Testing and commissioning	S	25	P,R
20	Handover letter	T	10	S

3.2. Critical Path Method (CPM)

Identify the Critical Path. The purpose of calculating progress for this project is to identify the critical path. In this step, it is preceded by performing a forward and backward calculation. Forward calculations are performed to determine Early Start (ES) and Early Finish (EF), while backwards calculations are performed to determine Latest Start (LS) and Latest Finish (LF). From these two calculations, a critical path can be identified which can be calculated as float/slack, which is the leeway for completing an activity. Forward and backward calculations, free slack and critical path can be seen in Tables 2, the forward and backward network diagrams can be seen in Figures 1 and 2 and critical network path can be seen in Figure 3 below:

Table 2. Forward and Backward Calculation, Slack Time and Critical Time (CPM Method)

No	Activities	Activities Code	Duration of Time (Hari)	Earliest Time (Forward)		Latest Time (Backward)		Slack	Free Slack	Noted
			t (day)	Start (ES)	Finish (EF)	Start (LS)	Finish (LF)			
					(EF= ES+t)			(SL= LS-ES)	(SL= LF-EF)	
1	*Receiving Purchase Order*	A	15	0	15	0	15	0	0	Critical
2	*Creating Invoice 100%*	B	10	15	25	15	25	0	0	Critical
3	*Receive 100%*	C	20	25	45	25	45	0	0	Critical
4	*Site Survey*	D	10	45	55	45	55	0	0	Critical
5	*Creating Budget*	E	20	55	75	55	75	0	0	Critical
6	*Sell in process*	F	20	75	95	75	95	0	0	Critical
7	*Shipping process (ITA)*	G	40	95	135	95	135	0	0	Critical
8	*Shipping process (SLO)*	H	35	95	130	104	139	9	9	Spare time
9	*Item clearance Process (ITA)*	I	10	135	145	135	145	0	0	Critical
10	*Item clearance Process (SLO)*	J	10	130	140	139	149	9	9	Spare time
11	*Item Arrival at Warehouse (ITA)*	K	5	145	150	145	150	0	0	Critical
12	*Item Arrival at Warehouse (SLO)*	L	5	140	145	149	154	9	9	Spare time
13	*Equipment Delivered on Site (ITA)*	M	14	150	164	150	164	0	0	Critical
14	*Equipment Delivered on Site (SLO)*	N	10	145	155	154	164	9	9	Spare time
15	*Equipment Unloading*	O	10	164	174	164	174	0	0	Critical
16	*Power Pug Installation*	p	7	174	181	197	261	23	23	Spare time
17	*Equipment Installation*	Q	10	174	184	174	184	0	0	Critical
18	*Repairing defect*	R	20	184	204	184	261	0	0	Critical
19	*Testing and commissioning*	S	25	261	229	204	229	0	0	Critical
20	*Handover letter*	T	10	229	239	229	239	0	0	Critical

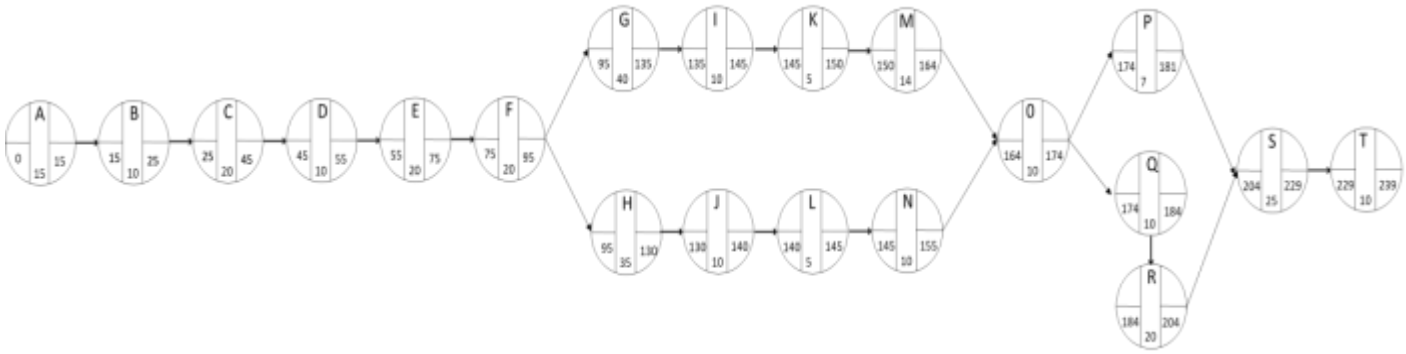

Figure 1. Advanced computation network CPM Method

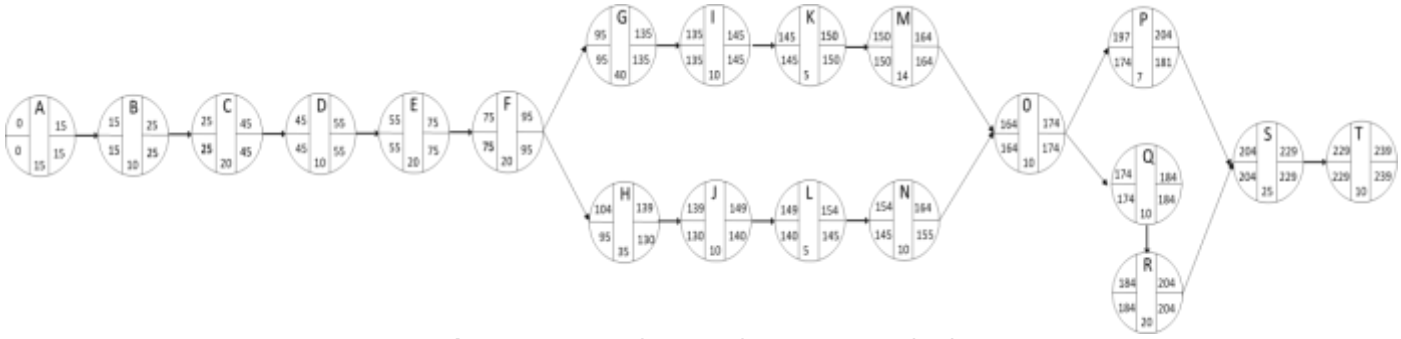

Figure 2. Network Countdown CPM Method

The critical path can be seen in Figure 3 below:

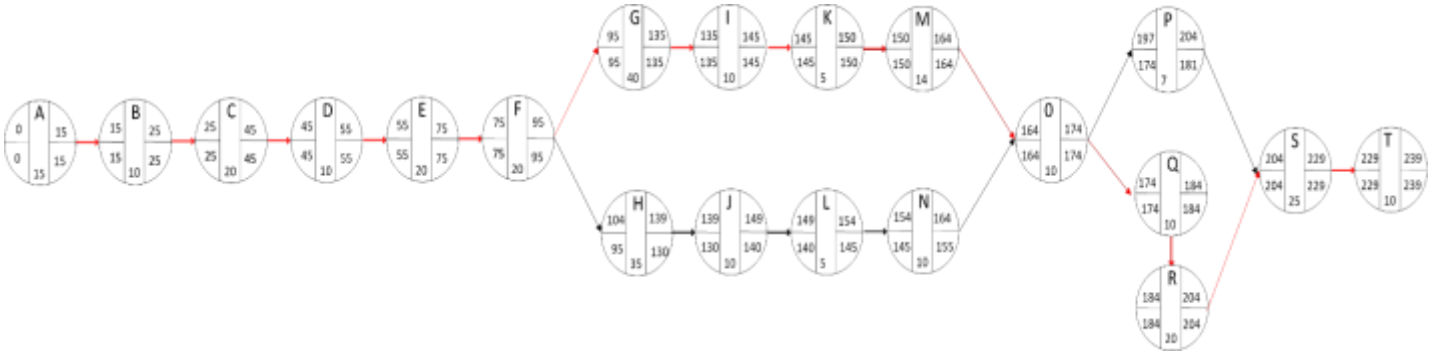

Figure 3. Critical Path Network CPM Method

3.3. Project Evaluation Review Technique (PERT)

The difference between CPM and PERT that is clearly visible is in the estimation of the activity period. If in CPM the time is determined with certainty (deterministic), then in PERT there are 3 known time estimates, namely:

1. Optimistic time (To), namely the possibility that activities can be completed in a shorter time.
2. The most frequent occurrence (Tm), namely the estimated time that usually occurs under normal circumstances.
3. Pessimistic time (Tp), namely the possibility that activities can be completed in a longer time.

Forward and backward calculations, free slack and critical path can be seen in Table 3, the forward and backward network diagrams can be seen in figures 4 and 5 below:

Table 3. Forward and Backward Calculation, Slack Time and Critical Time (PERT Method)

No	Activities Code	Predecessor	Duration of Time (day)	Earliest Time (Forward)		Latest Time		Slack	Note
			t (day)	Start (ES)	Finish (EF)	Start (LS)	Finish (LF)		
					(EF=ES +t)	(LS= LF-t)		(SL = LS- ES)	
1	A		15	0	15	0	15	0	Critical
2	B	A	10	15	25	15	25	0	Critical
3	C	B	20	25	45	25	45	0	Critical
4	D	C	10	45	55	45	55	0	Critical
5	E	D	20	55	75	55	75	0	Critical
6	F	E	20	75	95	75	95	0	Critical
7	G	F	47	95	142	95	142	0	Critical
8	H	F	44	95	139	105	149	10	Spare Time
9	I	G	16	142	158	142	158	0	Critical
10	J	H	14	139	153	149	163	10	Spare Time
11	K	I	9	158	167	158	167	0	Critical
12	L	J	7	153	160	163	170	10	Spare Time
13	M	K	12	167	179	167	179	0	Critical
14	N	L	9	160	169	170	179	10	Spare Time
15	O	M,N	11	179	190	179	190	0	Critical
16	P	O	7	190	197	213	220	23	Spare Time
17	Q	O	10	190	200	190	200	0	Critical
18	R	Q	20	200	220	200	220	0	Critical
19	S	P,R	26	220	246	220	246	0	Critical
20	T	S	12	246	258	246	258	0	Critical

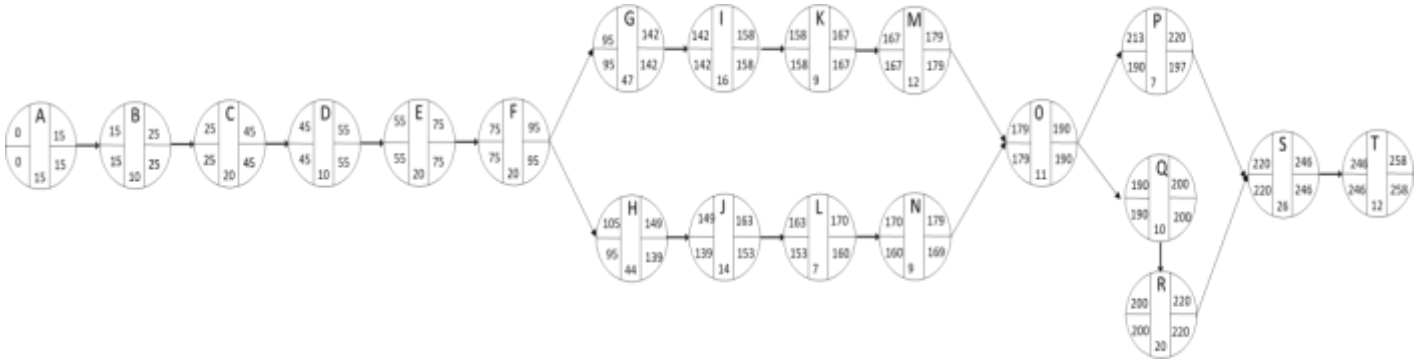

Figure 4. Network diagram Activity on Node (AON)

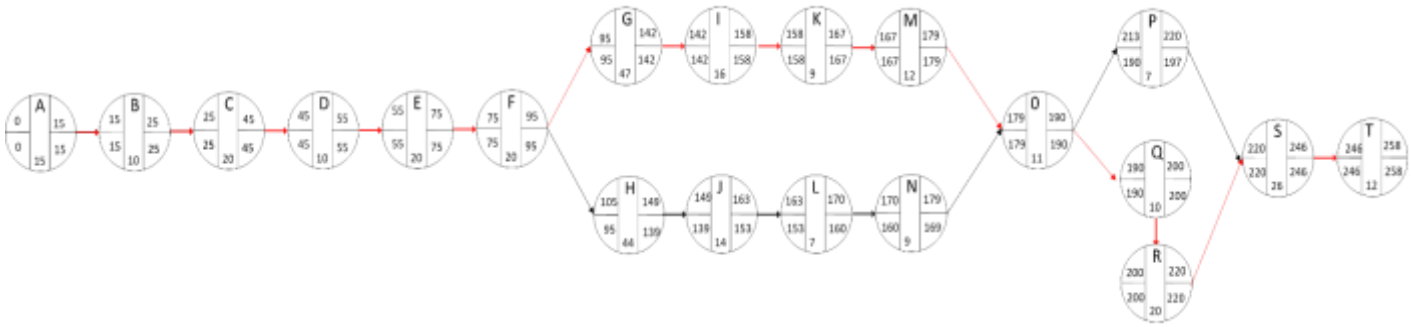

Figure 5. Network diagram Activity on Node (AON) Critical Path

Once the critical path is known, the next step is to calculate the variance (v) and standard deviation (S) for each project activity which can be seen in Table 4.

Table 4. Calculation of Variance (V) and Standard Deviation (S)

Activities Code	Period (day)				S	V
	TM	TO	TP	TE		
	Normal	Optimistic	Pessimistic	Activity Time	Standard Deviation	Activities Variant
A	15	10	20	15	1,67	2,78
B	10	7	13	10	1,00	1,00
C	20	16	24	20	1,33	1,78
D	10	2	18	10	2,67	7,11
E	20	7	33	20	4,33	18,78
F	20	15	25	20	1,67	2,78
G	40	30	92	47	10,33	106,78
H	35	30	94	44	10,67	113,78
I	10	5	51	16	7,67	58,78
J	10	5	39	14	5,67	32,11
K	5	2	32	9	5,00	25,00
L	5	2	20	7	3,00	9,00
M	14	5	11	12	1,00	1,00
N	10	4	10	9	1,00	1,00
O	10	3	23	11	3,33	11,11
P	7	3	11	7	1,33	1,78
Q	10	5	15	10	1,67	2,78
R	20	5	35	20	5,00	25,00
S	25	15	41	26	4,33	18,78
T	10	5	27	12	3,67	13,44

From the calculation results above, the value of the project completion time variant based on the critical path is 296.89 days with a standard deviation of √296.89 = 17.23 days. By using the normal curve probability of project completion time using the following formula:

T(d) = 239 days (settlement assumptions CPM)

$z = (d) - \sum Tekritis$ z = 239 – 258 = -1.10 ~0,1357

17,23

From the figures above, the number 0.1357 is obtained in the normal distribution table Z, so the probability of completing the project within 239 days is 13.57%.

4. CONCLUSIONS

Based on the results of data processing, the duration of project completion using the CPM method is 239 days, with the PERT method, the project can be completed within 258 days, so in this PERT analysis, the accelerated time is 48 days. The time difference between the CPM and PERT methods is 19 days. A comparison graph of methods and project completion times can be seen in Figure 6.

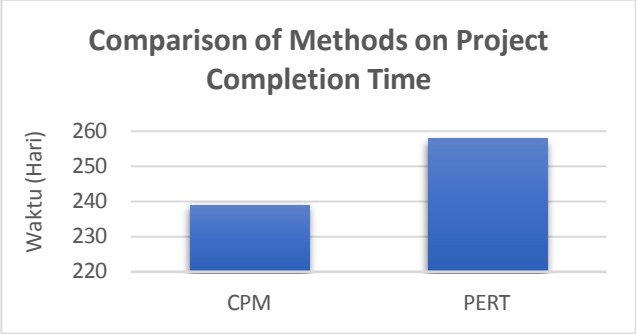

Figure 6. A comparison graph of methods and project completion times.

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