Time and Cost Optimization in Feasibility Test of CCTV Project using CPM and PERT

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Abstract*— Completing a closed-circuit television (CCTV) project on time and within budget is not an easy thing. Scheduling and planning in the CCTV project hold an essential role in predicting the aspects of time and project costs. The success or failure of a project can be viewed on the initial process of CCTV planning, including projecting the crash because of the absence of optimization in terms of plan which led to the in the effectively of the project. This research aims to find the trade-off between cost and optimal time required to complete the project of CCTV by using Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT). CPM and PERT are used to make working time and cost of the project more effective and efficient. The evaluation of this research uses data about the project time and expenses from computer vision (CV) Aditya IT Consultant, a software house based in Kediri, East Java. The expected duration is 73 days, and the normal cost is IDR 207,858,300. However, by using CPM and PERT, the optimal time is 48 days with the price IDR 168,608,300. The conclusion is CPM and PERT make the working time and cost of a project effective and efficient by reducing the completion time and cost up to 25 days and IDR 39,250,000.

***Keywords*— CCTV Project, Critical Path Method (CPM), Project Evaluation and Review Technique (PERT)**

I. INTRODUCTION

Indonesia as a developing country has a lot of development project whether it is long term or short term, whether it is a construction project of a building, bridge, road toll, telecommunication networks, or any others. The closed-circuit television (CCTV) installation project was no exception. The need for CCTV in every town is increasing rapidly in line with the economic growth of the city since CCTV helps to monitor or keep an eye on every corner in the city.

Every project has time restrictions according to the contract specified and must be completed before the arranged deadline. The failure of a project is usually due to the lack of project planning activities which result in the delaying of the finished time and the swelling of the operational cost specified in the contract.

The delay in the completion of the project itself is a disadvantage to both parties between the giver and the recipient of the project. Every project has a goal to be achieved. There are several steps to carry out the project, such as the project needs to be described from the largest to the smallest thing, depicting a diagram of the network, estimation the last project completion time monitor the course of the project [1]. There are reference limits, i.e. the cost or other things commonly called the budget allocated, scheduling, and quality. To find the optimal time and costs, there have been several previous studies with various methods such as the FMS Goal Programming and scheduling method [2], the Goal Programming method [3], the PERT method and the Goal Programming [4], Fuzzy Goal Programming method [5], and the Dynamic Programming and FMS Scheduling method [6]. Using the method of Project Evaluation and Review Technique (PERT) to analyze optimization time project so that it can be known how long the project is finished and looking into the possibility of acceleration the implementation of the project [3].

From previous research, goal programming is a method for optimizing time and costs, but the main focus of goal programming is not to search for a direct result. Goal programming works by minimizing the deviation between the goals that need to be achieved and the obtained results. Other methods, such as FMS scheduling, are methods that can optimize costs, time, product quality, and increase labour efficiency, but the weakness of this method are high initial set up costs, the requirement of skilled workers, and a more complicated system.

For many years, the approach has proved useful in resolving cases such as planning, scheduling, controlling, namely through the method of approach with Critical Path Method (CPM) and PERT. Because the PERT and CPM are a method of network-based techniques, it can help in terms of programming and monitoring of a project that is completed by the deadlines specified [7].

CPM is a method of network analysis work which puts optimization cost or budget of a project through reduction or accelerating project completion time [8]. The goal is reducing the interference between PERT method production and delay as well as being able to coordinate the thoroughly in an activity on the project.

The purpose of this study is to conduct a feasibility test to determine the optimization of time and costs on the CCTV project of CV. Adisatya IT Consultant. The achievement of optimization is by looking for the best critical path using the PERT method to get optimal time on the CCTV project. Next, to get the best cost, the CPM method will be used. Lastly, the test of the hypothesis will be conducted to find out the number of percentage of critical paths made by the PERT method; if the number is closer to 100%, then the calculation is acceptable.

II. RESEARCH METHOD

A. Critical Path Method (CPM)

CPM helps to decide the time of completion of the project in which all of the lines of the activities must be crossed and retrieved from an event the longest path of process model [6], [9]–[11]. If the activity line interfered, then the project will be delayed. In the Critical Path Method, some essential things are associating with this method. Those things are:

1) E (The Earliest Event Occurrence Time) is the fastest time in the event,
2) L (The Latest Event Occurrence Time) is the latest incident is still allowed on a project,
3) ES (The Earliest Activity Start Time) is the earliest Time is starting a project,
4) EF (The Earliest Activity Finish Time) is the earliest complete time of a project,
5) LS (The Latest Activity Start Time) is the time delay in a project that can be started without slowing down the project,
6) D is the duration of an activity,
7) A Predecessor is a group of activities that need to be done before doing another activity,
8) Activity time is the complete time of a project; which can be deterministic or probabilistic. When deterministic time natures activities, those activities are completed within a constant. Meanwhile, when the activity time is probabilistic, those activities are completed within a random value.

There are three steps to calculate the CPM. The first step is the Forward Pass. Forward Pass aims to estimate the earliest finish time (EF), the earliest start time (ES), and the earliest occurrence time (E). Starting from the initial event to the terminal event, Equation (1) describes the Forward Pass calculation. Forward Pass calculation adds the earliest start time and duration to obtain the earliest finish time.

$$EF = ES + D \tag{1}$$

where:

EF = earliest finish
ES = earliest start
D = duration

The second step is the Backward Pass. The goal of the Backward Pass is to calculate the latest finish time (LF), the most recent start time (LS), and the newest occurrence time (L) [12]. In contrary to the Forward Pass, the Backward Pass calculation start from the terminal event to the initial event [13]. Equation (2) is the Backward Pass calculation. The Backward Pass calculates the latest start time by adding the newest finish time with duration. Finally, find the difference between the Forward Pass and Backward Pass to obtain the critical path.

$$LS = LF - D \tag{2}$$

where:

LS = latest start
LF = latest finish
D = duration

B. Program Evaluation and Review Technique (PERT)

PERT is a model that depicts the fulfillment of events [14]. By using PERT, there is the reduction of-of needed times to finish a set of works. PERT method through the Beta distribution that is used as a time approach for getting the completion time of the project to make it looks realistic [14], [15]. Then, the average time based on PERT is denoted as expected return, which is calculated by Equation (3). The division of the total of optimistic, most likely, and pessimistic time with 6 is the value of the expected return [3].

$$Te = \frac{a + 4m + b}{6} \tag{3}$$

where:

Te = Expected return
a = Optimistic time
m = Most likely time
b = Pessimistic time

Besides expected return, Equation (4) explains how to measure the amount of uncertainty in the Optimistic Time and the Pessimistic Time. The amount of risk is obtained by calculating 16.667 per cent of the reduction in pessimistic time with optimism time. Then, Equation (5) describes the calculation of the variants — 16.667 per cent of the powers of the decrease in cynical time with optimism time.

$$S = \frac{1}{6}(b - a) \tag{4}$$

where:

S = amount of uncertainty (standard deviation)
a = optimistic time
b = pessimistic time

$$V(te) = S^2 = \frac{(b - a)^2}{6} \tag{5}$$

where:

V (te) = variants of activities
S = amount of uncertainty(standard deviation)
a = optimistic time
b = pessimistic time.

C. Estimation of The Possibility of The Target Schedule by using Hypothesis Testing

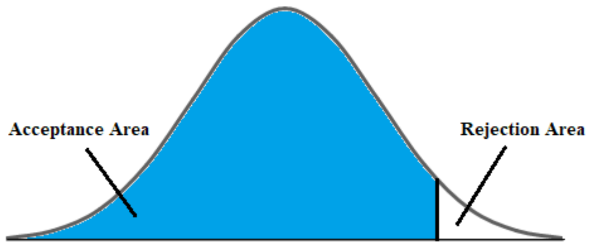
Equation (6) is used to find out the possibility of reaching the target schedule. This equation can be done by connecting the expected time *TE* and the Target *T(d)*. In this paper, the expected time is obtained time by using PERT and the target is the expected duration of the project (based on the total of most likely time in PERT).

$$Zhit = \frac{T(d) - TE}{S} \tag{6}$$

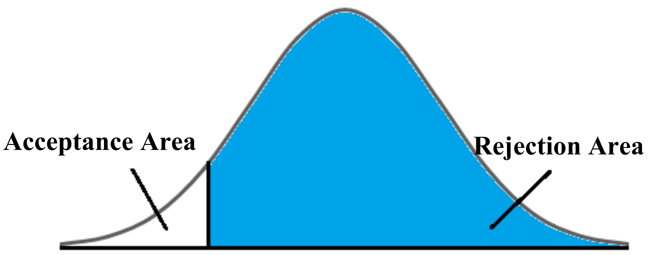
where:

Zhit = the possibility of reaching the target
T(d) = target
TE = expected time.

Based on the normal distribution by Gordon [16] and *Zhit* value, the value of the normal distribution (*Ztable*) with a range of values at 0 to 1 is obtained. Then, calculate the residual value of *Ztable* (*Zts*), if the *Zts* value is smaller than Stable, accept H0 or as can be seen in Fig. 1(a). Fig. 1(a) shows the curve with the area of acceptance is greater than the area of rejection. However, if the value of *Zts* is greater than Stable, then reject H0, which is depicted as Fig. 1(b) where the curve with the area of acceptance is smaller than the area of rejection.



(a) Acceptance area curve is greater than the rejection area



(b) Rejection area curve is greater than the acceptance area

Fig. 1. The curve of normal distribution

TABLE I. MAIN ACTIVITY PROJECT CCTV AS THE INPUT OF CPM

Act No	Act Name	Predecessor	*Note*	*Duration* (days)
1	A	-	Request For CCTV project	3
2	B	A	Location Survey	3
3	C	A	Network Survey	3
4	D	A	Tower Survey	3
5	E	B,C,D	Create Proposal	7
6	F	E	Checking Electricity	3
7	G	E	Checking Network	3
8	H	F	PLN Licensing	4
9	I	G	Telkom Licensing	4
10	J	E	Procurement of Equipment	17
11	K	H,I,J	Construction by 3rd Party	7
12	L	K	CPE and Wireless installation	7
13	M	K	Ground Installation	7
14	N	L,M	Test Link	1
15	O	N	Report	1
Total of expected duration				**73**

where:
ActNo : the number of activity
ActName : the name of activity
Predecessor : the previous activity of the activity
Note : the description of activity
Duration : the duration of executing activity in days.

To perform a test of the hypothesis, firstly is to determine the Hypothesis null (H_0) and the alternative Hypothesis (H_1) [16]. If the value is greater than the value *Zhit Ztable*, then accept H. Conversely, if *Ztable* is smaller than *Zhit,* then accept H_0.

III. RESULT AND ANALYSIS

The method used for this study is the CPM method, which is combined with the PERT method. The main activity in the CCTV Project can be seen in TABLE I. Several activities are Location Survey, Network Survey, Checking Network and PLN Licensing. Besides events, TABLE I describes the Predecessor as the previous activities and Duration as the execution time of activities. For example, Checking Network has E as its Predecessor and three as its Duration. It means Create Proposal is executed before Checking Network, and Checking Network needs three days.

A. Calculating Critical Path with CPM

In CPM calculations, projects can only have one initial event (Start) and one terminal event (finish). The Start is the zero-day if it occurs when the delay is finished.

The final calculation of the CPM can be seen in Fig. 2. There are several steps to obtain the final calculation. The first step is to draw a critical path network diagram by entering the duration of the project according to its activities. After creating a network diagram, an advanced calculation processor commonly known as forwarding Pass is done in a way. For example, in Activity K, there is predecessor Activity H, I, J. Activity K cannot be done until the activities of H, I, J has been completed, therefore to determine the ES activity K must be compared with the three EF values H, I, J and for the forward pass taken is the largest value. After all the Forward Pass process is done, the duration of the CCTV project can be seen as 46 days. Based on the Forward Pass calculation, Activity A results in EF value of 3, Activity B results in EF value of 6, Activity C results in EF value of 6, Activity D results in EF value of 6, and Activity O results in EF value of 46.

The first step of CPM is a forward pass, which is depicted in Fig. 2. If there are several previous activities, the earliest start time (ES) of the activity is the highest EF of the previous activities. It can be seen in activity K. The ES of K is 30 because the highest EF is the EF of J. Then, the obtained result by forwarding Pass will be processed by Backward Pass. In the process of Backward Pass, the value taken is the smallest LS value, so LS activity F = 23, LS activity G = 23, LS activity J = 13 taken is LS Activity J = 13 lowest value. The lines determine the Forward Pass and Backward Pass processes according to previous calculation. Slack or also called delay is obtained from knowing the numbers of ES and LS. Slack itself is the difference from Slack = LS-ES. After getting slack, we can find out the critical path with the results Slack=0. The result of the final calculation of CPM is Fig. 3.

B. WinQSB for evaluation results obtained by CPM

Calculations using WinQSB software to obtain cost values from CCTV projects. Based on the real record in the CCTV project, the main Activities are on TABLE II. The total cost of the CCTV project was Rp. 207.858.300 by the experts. WinQSB gets the Solve and Analyse-it. According to calculation on TABLE III, where AN is Activity Number, AcN is Activity Name, and NT is Normal Time. The Y and N in TABLE III are Yes and No.

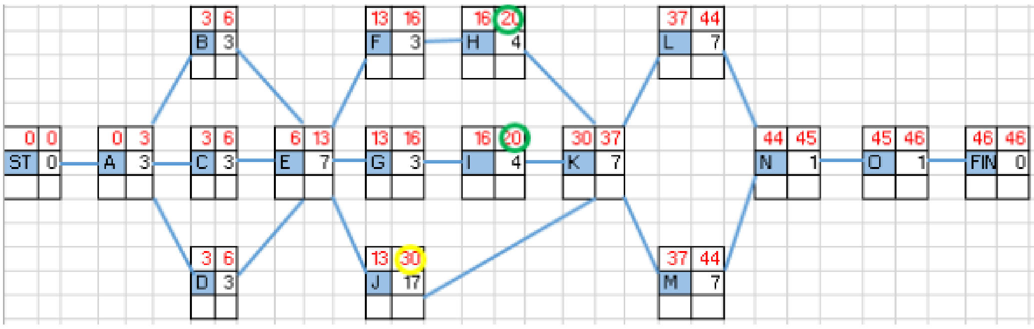


Fig. 2. The first step of CPM : Forward pass

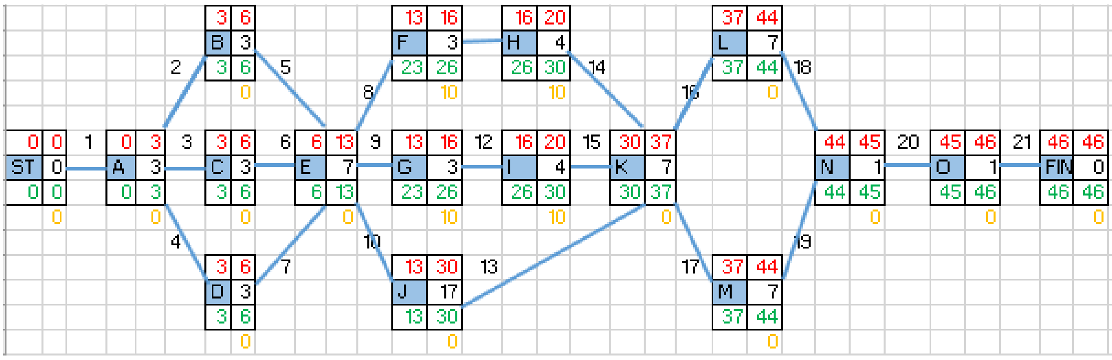


Fig. 3. Final calculation of CPM Diagram

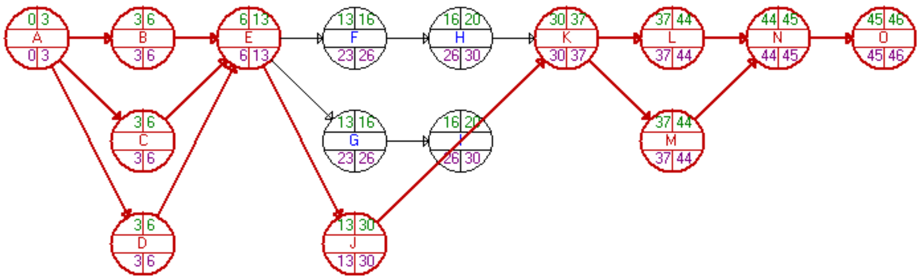


Fig. 4. Network activity using WinQSB

TABLE II. THE MAIN ACTIVITY OF THE CCTV PROJECT USING WINQSB

AN	AcN	Predecessor	NT	Normal Cost	
1	A	-	1	IDR	500,000
2	B	A	2	IDR	300,000
3	C	A	2	IDR	300,000
4	D	A	2	IDR	300,000
5	E	B,C,D	5	IDR	500,000
6	F	E	2	IDR	300,000
7	G	E	2	IDR	300,000
8	H	F	3	IDR	.850,000
9	I	G	3	IDR	.800,000
10	J	E	14	IDR	1,858,300
11	K	H,I,J	5	IDR	50,850,000
12	L	K	5	IDR	8,000,000
13	M	K	5	IDR	4,200,000
14	N	L,M	1	IDR	550,000
15	O	N	1	IDR	250,000
Total of normal cost				**IDR**	**207,858,300**

where: AN = activity number
AcN = activity name
NT = normal time.

TABLE III. THE RECORD OF PROBLEM SOLVING BY WINSQB

AN	AcN	CP	AT	ES	EF	LS	LF	Slack
1	A	Y	3	0	3	0	3	0
2	B	Y	3	3	6	3	6	0
3	C	Y	3	3	6	3	6	0
4	D	Y	3	3	6	3	6	0
5	E	Y	7	6	13	6	13	0
6	F	N	3	13	16	23	26	10
7	G	N	3	13	16	23	26	10
8	H	N	4	16	20	26	30	10
9	I	N	4	16	20	26	30	10
10	J	Y	17	13	30	13	30	0
11	K	Y	7	30	37	30	37	0
12	L	Y	7	37	44	37	44	0
13	M	Y	7	37	44	37	44	0
14	N	Y	1	44	45	44	45	0
15	O	Y	1	45	46	45	46	0
Project Completion Time = 47.67 days								
Total Cost of Project = IDR 207,858,300								
Number of Critical Path(s) = 6								
Total Cost based on CP = IDR 168,608,300								

where: CP = critical path
AT = activity time
ES = earliest start
EF = earliest finish
LS = latest start
LF = latest finish
AcN = activity name

TABLE IV. CRITICAL PATH USING WINSQB

AN	CP1	CP2	CP3	CP4	CP5	CP6
1	A	A	A	A	A	A
2	B	B	C	C	D	D
3	E	E	E	E	E	E
4	J	J	J	J	J	J
5	K	K	K	K	K	K
6	L	M	L	M	L	M
7	N	N	N	N	N	N
8	O	O	O	O	O	O
CT	46	46	46	46	46	46

where: AN = activity number
CP = critical path
CT = completion time

The project completion time is 46 days, and the initial CCTV project cost is IDR 207,853,500 to IDR 168,608,300 with 6 Critical Paths. The project cost is obtained by calculating the activities that are included in Critical Path. This Critical path can be seen in TABLE IV, and the network activity of the CCTV project processing business can be seen in Fig. 4. There are six obtained critical paths. The network activity in Fig. 4 visualizes the obtained critical paths in TABLE IV. Activity J is included in all critical paths, and the combination of activity B, C, D and the combination of activity L, M are also included in the critical paths.

C. Calculations critical path by using PERT

For each activity, the model in the PERT method has three estimated time, first Optimistic Time *(a)*, Most Likely Time *(m)*, and finally Pessimistic Time *(b)*.

From the calculation results using PERT as on TABLE VI, there are 6 Critical Paths. The critical paths are the same as Fig. 4. The result of the calculation can be seen in TABLE V by using Winqsb, where AN is Activity Number, AcN is Activity Name, AMT is Activity Mean Time, Activity Time Distribution and SD is Standard Deviation. The optimal time is 47.67 days to complete the CCTV project.

TABLE VI. MAIN ACTIVITY PROJECT CCTV USING PERT

Activity Number	Activity Name	Predecessor	*a*	*m*	*b*
1	A	-	1	3	5
2	B	A	2	3	5
3	C	A	2	3	5
4	D	A	2	3	5
5	E	B,C,D	5	7	10
6	F	E	2	3	4
7	G	E	2	3	4
8	H	F	3	4	6
9	I	G	3	4	6
10	J	E	14	17	22
11	K	H,I,J	5	7	10
12	L	K	5	7	10
13	M	K	5	7	10
14	N	L,M	1	1	3
15	O	N	1	1	3

where: *a* = optimistic time
m = most likely time
b = pessimistic time

A manual calculation can be done in the manner described above, where Activity Mean Time is Expected Return (*Te*). The example of the calculation of *Te* activity A, B, and O are explained in Equation (7), Equation (8), and Equation (9). The calculations are based on the Equation (3). The total time obtained by PERT method is 48 days (rounding off 47.67).

$$Te(A) = \frac{a + 4m + b}{6} = \frac{1 + 4(3) + 5}{6} = 3 \quad (7)$$

$$Te(A) = \frac{a + 4m + b}{6} = \frac{2 + 4(3) + 5}{6} = 3.167 \quad (8)$$

$$Te(O) = \frac{a + 4m + b}{6} = \frac{1 + 4(1) + 3}{6} = 1.333 \quad (9)$$

D. Hypothesis testing for CCTV project analysis activities

Hypothesis Test is done to determine whether the CCTV Project can be completed with optimal time, determined by

TABLE V. ACTIVITY ANALYSIS PROJECT CCTV USING PERT

AN	AcN	CP	AMT	ES	EF	LS	LF	Slack	ATD	SD
1	A	Yes	3	0	3	0	3	0	3-time estimate	0.6667
2	B	Yes	3.1667	3	6.1667	3	6.1667	0	3-time estimate	0.5
3	C	Yes	3.1667	3	6.1667	3	6.1667	0	3-time estimate	0.5
4	D	Yes	3.1667	3	6.1667	3	6.1667	0	3-time estimate	0.5
5	E	Yes	7.1667	6.1667	13.3333	6.1667	13.3333	0	3-time estimate	0.8333
6	F	No	3	13.3333	16.3333	23.5	26.5	10.1667	3-time estimate	0.3333
7	G	No	3	13.3333	16.3333	23.5	26.5	0	3-time estimate	0.3333
8	H	No	4.1667	16.3333	20.5	26.5	30.6667	10.1667	3-time estimate	0.5
9	I	No	4.1667	16.3333	20.5	26.5	30.6667	10.1667	3-time estimate	0.5
10	J	Yes	17.333	13.3333	30.6667	13.3333	30.6667	0	3-time estimate	1.3333
11	K	Yes	7.1667	30.6667	37.8333	30.6667	37.8333	0	3-time estimate	0.8333
12	L	Yes	7.1667	37.8333	45	37.8333	45	0	3-time estimate	0.8333
13	M	Yes	7.1667	37.8333	45	37.8333	45	0	3-time estimate	0.8333
14	N	Yes	1.3333	45	46.3333	45	46.3333	0	3-time estimate	0.3333
15	O	Yes	1.3333	46.3333	47.6667	46.3333	47.6667	0	3-time estimate	0.3333
Project Completion Time = 47.67 Days										
Number of Critical Path(s) = 6										

where: AN = activity number
AcN = activity name
CP = critical path
AMT = activity mean time
ES = earliest start
EF = early finish
LS = latest start
LF = latest finish
ATD = activity time distribution
SD = standard deviation.

Hypothesis Test is done to determine whether the CCTV Project can be completed with optimal time, determined by looking for standard deviations and variants first. From the calculations in the (2), the obtained standard deviation is 9.16. Next, test criteria is determined by using *Zhit* value in *Ztable*. Based on the formula in Equation (4), *Zhit* obtains 2.76 (*T(d)* is 73 and *TE* is 47.67). Then, entering the *Zhit* value in table Z (normal distribution) is 0.9971 or 99.71%. This shows the area under the standard normal curve from 2.76 to the left of the curve that is 99.71%. Because the entire area of the normal curve is 100% while the area of acceptance is 99.71% so that the rejection area is 0.29% which is the residual area of the entire area of the normal curve. Because the receiving area is greater than the rejection area, accept H_0.

IV. Conclusion

This paper discusses the problem of optimizing costs and time on CCTV projects CV. Adisatya IT Consultant. With the calculation using the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) methods.

Firstly, PERT method is used to determine the best project time. This research uses the time obtained by PERT method, not CPM method, because PERT considers optimistic and pessimistic time, so the time calculation is more detail. Next, to get the best cost, the CPM method is used. These two steps result in critical paths along with the costs. Finally, the hypothesis testing is conducted to find out the percentage number of the critical path that can be possibly done by using PERT method.

The opportunity for the CCTV project to be completed is 99.71%, so the predicted project time by using PERT, which is 48 days, is acceptable. By using PERT and CPM, the optimal time is 48 days with the price IDR 168,608,300 (reducing the completion time and cost up to 25 days and IDR 39,250,000).

Acknowledgment

The authors would like to thank Institut Teknologi Sepuluh Nopember, The Ministry of Research, Technology and Higher Education of Indonesia, Direktorat Riset dan Pengabdian Masyarakat, and Direktorat Jenderal Penguatan Riset dan Pengembangan Kementerian Riset, Teknologi, dan Pendidikan Tinggi Republik Indonesia for supporting the research.

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