Study on Cost Analysis and Time Acceleration With CPM Method And Earned Value Method at Madegan Market Renovation Work of Ponorogo Regency

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Abstract

Cost and time deviation gives indication that construction project management is poor. In the reality shows that project completion time varies, as result the estimated time of project completion cannot be ensured. The research objectives include (1) Obtaining estimation of time needed to complete the renovation work, (2) Obtaining estimation of final project cost to the work contract value for renovating, (3) Gaining profit or loss in doing the work renovation of Badegan Market. The research method used CPM and Earned Value methods. The results showed that (1) Using the Earned Value method, the work performance of market renovation project was as expected and reached the work target and experienced acceleration, the estimated time of project completion was 79.09 days. By using the critical path determination to the CPM, the time it takes to complete the renovation project was 80 days, can be accelerated 40 days from initial planning 120 days, (2) The estimated cost of renovation project was equal to the contract value, amounting to IDR 3,673 Billion, (3) Based on the Cost Variance value, in the Market Renovation project, the contractor earns profit or costs incurred by the contractor less than the available budget of IDR 283,494 Million.

Keywords: cost variance, CPM, earned value

INTRODUCTION*

A construction project, controlling project costs is important in the process of managing project costs [1]. In its activities many problems are found, such as material wasteful use, unskilled labor and the time to complete projects that are not on time, causing wasteful costs that are not according to plan. So costs that have been issued and the time used to complete job must be measured continuously the deviation from the plans. Significant time and cost deviations indicate poor project management.

To resolve these problems there are several methods used to control project, the CPM method *(Critical Path Method)* or critical path techniques and Earned Value Analysis (EVA) method. *Critical Path Method* (CPM) is network analysis that seeks to optimize the total project completion time. While *Earned Value Analysis* is one of the tools used in project management that integrates costs and time [2]. The concept of *earned value* presents three dimensions, namely the physical completion of the project (*the percent* complete) that reflects the planned absoIDRtion of costs (*budgeted cost)*, the actual costs that have been incurred or called the *actual costs* and what is obtained from the costs that have been incurred or called *earned value.* From the three dimensions, with the concept of *earned value,* can be connected between cost performance and time derived from the calculation of variants of cost and time [3].

With project performance indicators based on cost and time, it is possible to take preventative measures so that project implementation goes according to plan. This was applied in this research at the work of renovating the Badegan Market in Ponorogo Regency in accordance with the agreed contract time, which was 120 days. Control needs to be done on this renovation work, because the project implementation has been delayed. Controlling costs and time is done so that the late time of implementation can be prevented. In addition, additional costs due to the delay can be optimized.

MATERIAL AND METHOD

The method used is the quantitative research with data collection of secondary and primary data. The study location was conducted at Badegan Market, Ponorogo Regency. The data analysis method used is the *Critical Path Method* (CPM) and the *Earned Value* method. CPM is network analysis that optimizes the total project completion time. Whereas *Earned Value* is tool used in project management that integrates costs and time [4]. The steps in CPM analysis are

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(1) Work Time Schedule; (2) Re-engineering of Work Implementation Using CPM Method; (3) Making *Network* Diagram; (4) Determine the Project Activity Time. While the stages in the *Earned Value Analysis* method are (1) Calculating the value of ACWP (*Actual Cost of Work Performance)*, BCWS *(Budgeted Cost Work Schedule),* BCWP *(Budgeted Cost for Work Performed)*; (2) Calculations based on cost aspects; and (3) Calculations based on time aspects. After analysis with both methods of analysis, the results obtained can be compared between the CPM and the *Earned Value* results*.* The final step is the discussion and conclusion by means of discussing calculations results and conclusion made.

Data Collection

The data used in this study are secondary and primary data obtained from the Department of Trade Industry Cooperatives and SMEs, namely the time schedule and S-curve project implementation plan, daily reports, weekly work reports, budget plans, direct costs and indirect costs of project implementation.

RESULT AND DISCUSSION

1. Project Data

The research location is Badegan Market, Ponorogo Regency. Renovation work packages as follows:

Job name   : Badegan Market Renovation
Scope of work   : Badegan Market Renovation
Total value of HPS : IDR 3,683,734,000.00
Implementation   : 120 Calendar Days
Work plan implementation schedule as table 1.

Table 1.   Budget Plan of Badegan Market Renovation in Ponorogo Regency

No	Type of work	Total Price (IDR)	Weight
I	Relocation Work		
A	Peonage	18,000,000.00	0.539
B	Earthwork	6,874,400.00	0.206
II	Preparatory work		
A	Preparatory work	196,889,592.00	5.896
III	Market stalls work		
A	Earthwork	230,129,789.00	6.890
B	Brick laying work	252,850,946.00	7.570
C	Concrete works	565,719,276.00	16.940
D	Steel Frame Work	1,535,833,640.00	45.985
E	Roofing Work	230,488,300.00	6.900

No	Type of work	Total Price (IDR)	Weight
F	Floor work	143,903,800.00	4.310
G	Sanitation Work	29,760,000.00	0.891
H	Electrical Installation Work	16,958,400.00	0.509
IV	Paving Work	112,366,400.00	3.364
A.	Total Work Prices	3,339,774,543.00	100.000
B.	Value Added Tax (VAT) = 10% x A	333,977,454.30	
C.	Total Price = A + B	3,673,751,997.30	
	Rounded up	3,673,747,000.00	

From the time schedule for carrying out the work, the following work implementation activities are made:

Table 2. Work Implementation Activities

No	No. Activity	Work Type	Done activities	Time (days)
I		Relocation Work		
A		Peonage	-	
B	1	Earthwork	-	7
II		Preparatory work		
A	2	Preparatory work	-	7
III		Market stalls Jobs		
A	3	Earthwork	1, 2	14
B	4	Brick laying work	5	7
C	5	Concrete works	3	14
D	6	Steel Frame Work	4	7
D	6	Steel Frame Work	5	28
E	7	Roofing Work	6	14
F	8	Floor work	6	14
G	9	Sanitation Work	10	3
H	10	Electrical Installation Work	7, 8, 11	7
IV	11	Paving Work	6	14

Renovation Activities Realization of Badegan Market of Ponorogo Regency During 120 days, as shown in Table 3.

Table 3. Renovation Activities   Realization of Badegan Market of Ponorogo Regency During 120 days

No	Month	Sunday	Period	Weekly Realization Weight	Weekly Budget Realization (IDR)	Cumulative Weekly Realization Weight	Cumulative Weekly Budget Realization (IDR)
1	October	1	10 - 16	0.480	17,640,941.94	0.480	17,640,941.94
		2	17 - 23	3.051	112,070,287.48	3.531	129,711,229.42
		3	24 - 30	2.948	108,289,362.78	6.478	238,000,592.19
2	November	4	31 - 06	1.723	63,285,704.16	8.201	301,286,296.35
		5	07 - 13	4.246	155,998,417.75	12.447	457,284,714.10
		6	14 - 20	8.481	311,569,984.10	20.928	768,854,698.20
		7	21 - 27	8.481	311,569,984.10	29.409	1,080,424,682.30
3	December	8	28 - 04	11.899	437,141,375.53	41.308	1,517,566,057.83
		9	05 - 11	11.899	437,141,375.53	53.207	1,954,707,433.35
		10	12 - 18	7.664	281,569,809.19	60.872	2,236,277,242.54
		11	19 - 25	7.664	281,569,809.19	68.536	2,517,847,051.73
4	January	12	26 - 01	7.664	281,569,809.19	76.200	2,799,416,860.91
		13	02 - 08	7.664	281,569,809.19	83.865	3,080,986,670.10
		14	09 - 15	6.901	253,537,445.31	90.766	3,334,524,115.42
		15	16 - 22	3.677	135,088,803.00	94.443	3,469,612,918.42
5	February	16	23 - 29	2.703	99,316,516.52	97.147	3,568,929,434.94
		17	30 - 6	2.853	104,822,562.36	100.000	3,673,751,997.30
			Jumlah	100.000	3,673,751,997.30		

2. Reengineering Work with Critical Path Method (CPM)

Critical Path Determination

The completion of the Badegan market renovation activity in Ponorogo Regency for 120 days was felt to be too long. As a first step in reengineering, the slack / slack calculation of the activity (i, j) is calculated, which consists of total float and free float.

Total float is the time amount in which the activity completion time can be postponed without affecting the fastest time of completing the work as whole, therefore this total float is calculated by finding the difference between the activity slowest start and the activity fastest start (LS-ES), or you can also find the difference between the time the activity is completed at the latest and the time that activity is completed (LF-EF). In this case, only one is chosen [5].

If the equation S = LS - ES is used, the total activity float (i, j) is $S_{(i,j)} = LS_{(j)} - ES_{(i,j)}$. From the backward calculation it is known that $LS_{(i,j)} = TL_{(j)} - t_{(i,j)}$. While from forward calculations $ES_{(i,j)} = TE_{(i)}$, then $S_{(i,j)} = TL_{(j)} - t_{(i,j)} - TE_{(i)}$.

If the equation S = LF - EF is used, the total activity float (i, j) is $S_{(i,j)} = LF_{(j)} - EF_{(i,j)}$. From forward calculations it is known, that $EF_{(i,j)} = TE_{(i)} + t_{(i,j)}$. While from the backward calculation of $LF_{(i,j)} = TL_{(i)}$, then $S_{(i,j)} = TL_{(j)} - TE_{(i)} - t_{(i,j)}$.
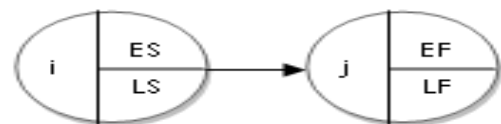

Figure 1. Total Float

Where:
i, j   = activity i to activity j
d ij   = duration of activities (i, j), i <j
ES i   = the fastest start time of event i
ES j   = the fastest initial time of event j
EF ij   = fastest time of event (i, j)
LF i   = end time late for event i
LF j   = late time of event j
LS ij   = time overdue (i, j)

Free float activities (i, j) are calculated by finding the difference between the fastest occurrence of the event at the end of the activity and the fastest completion of the activity (i, j). Or $SF_{(i,j)} = TE_{(j)} - EF_{(i,j)}$. From forward calculations $EF_{(i,j)} = TE_{(i)} + t_{(i,j)}$ is obtained, then $SF_{(i,j)} = TE_{(j)} - TE_{(i)} - t_{(i,j)}$.

From the calculation of the slack time, the critical path can be determined, where the critical path has slack time = 0, so it can be explained as follows:

a. Tracks that have slack time S = SF = 0 are:

Activity		Type of work
I B	(0,1)	Earthwork for Relocation
II A	(0,2)	Preparatory work
III A	(1,3)	Land Works for market stalls
III C	(3,5)	Concrete works
III D	(5,6)	Steel Frame Work

III E	(6,7)	Roofing Work
III F	(6,8)	Floor work
IV	(6,11)	Paving Work
III H	(7,10)	Electrical Installation Work
III H	(6,10)	Electrical Installation Work
III H	(11,10)	Pekerjaan Instalasi Listrik
III G	(10,9)	Pekerjaan Sanitasi

b. The completion period of Badegan Market Renovation Project in Ponorogo Regency was 80 days

Network Diagram Making

From the work implementation, then network diagram is made as shown in Figure 2.
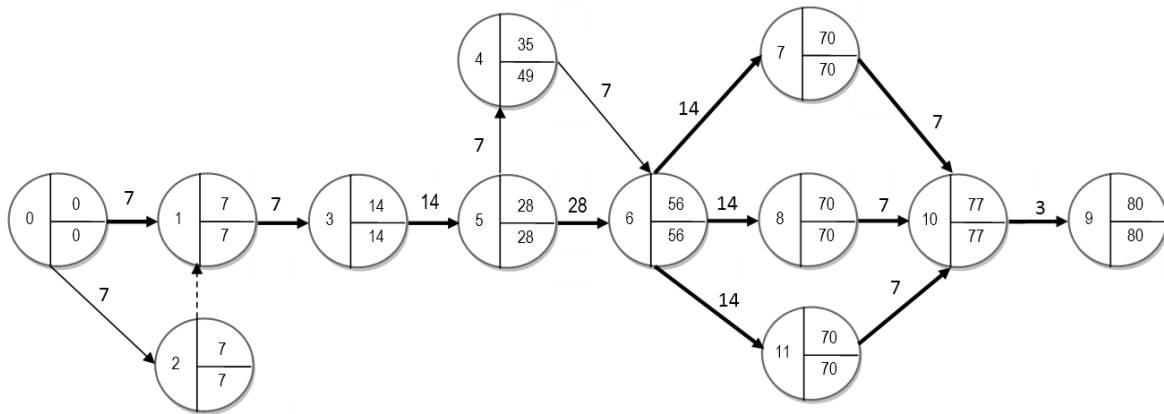
Figure2. Network Diagram of Work Implementation For Badegan Market Renovation in Ponorogo Regency

In figure 2, after re-engineering, forward and backward calculations, the critical paths formed are:

Track: 0-1-3-5-6-7-10-9

Track: 0-1-3-5-6-8-10-9

Track: 0-1-3-5-6-11-10-9

The schedule for carrying out renovation work at Badegan Market in Ponorogo Regency can be completed in 80 days, work can be accelerated 40 days from the time the initial schedule of work was carried out for 120 days.

Accelerated Activity Schedule

Based on the Network Diagram of Badegan Market Renovation Work Implementation in Ponorogo Regency, which can be completed in 80 days and there is no change in costs so that the work time difference can be used to evaluate and improve. Then be prepared Schedule of Badegan Market Renovation Activities of Ponorogo Regency For 80 days as follows:

Table 4. Realization of Badegan Market Renovation Activities in Ponorogo Regency for 80 days

No	Month	Sunday	Period	Weekly Realization Weight	Weekly Budget Realization (IDR)	Cumulative Weekly Realization Weight	Cumulative Weekly Budget Realization (IDR)
1	October	1	10 - 16	6.836	251,137,686.54	6.836	251,137,686.54
		2	17 - 23	10.847	398,491,879.15	17.683	649,629,565.68
		3	24 - 30	9.792	359,733,795.58	27.475	1,009,363,361.26
2	November	4	31 - 06	10.935	401,724,780.90	38.410	1,411,088,142.16
		5	07 - 13	5.604	205,877,061.93	44.014	1,616,965,204.09
		6	14 - 20	10.271	377,331,067.64	54.285	1,994,296,271.73
		7	21 - 27	7.449	273,657,786.28	61.734	2,267,954,058.01
3	December	8	28 - 04	10.922	401,247,193.15	72.656	2,669,201,251.16
		9	05 - 11	10.659	391,585,225.39	83.315	3,060,786,476.55
		10	12 - 18	10.198	374,649,228.68	93.513	3,435,435,705.24
		11	19 - 25	4.356	160,028,637.00	97.869	3,595,464,342.24
		12	26 - 28	2.131	78,287,655.06	100.000	3,673,751,997.30
			Jumlah	100.000	3,673,751,997.30		

3. Reengineering the Work with Earned Value Method

The method used in controlling costs and time in the field is to use Time Schedule. Based on the 80 days of Badegan Market renovation activities in Ponorogo Regency, the value of Budgeted Cost of Work Schedule (BCWS), Budgeted Cost of Work Performance (BCWP), Actual Cost for Work Performed (ACWP) can be determined [6].

- BCWS (*Budgeted Cost of Work Schedule*)

Based on the S-curve graph of planning and project realization, the percentage of work until the 7th week, because in the 7th week there was an increase in the percentage of the work volume. The actual physical percentage (realization) of the project tends to be smaller or behind schedule.

Analysis of earned value wasdone in the 7th week. So that the valuation of the Badegan Market Renovation Project in Ponorogo Regency was conducted in the 7th week. From the BCWS values accelerated every week accumulated until the 7th week, as follows:

BCWS = % planed weight x project value
      = 7.664% x IDR 3,673,751,997.30
      = IDR 281,569,809.19

The 7th week of BCWS value is IDR.281,556,353.07 then accumulated in the previous week, so the value of the 7th week of BCWS is IDR 2,242,237,794.03.

- BCWP (*Budgeted Cost for Work Performed*)

The accelerated BCWP calculation was obtained from the weight of the work realization against the budget plan and then accumulates every week. The weight of work realization is obtained from the weekly progress report on the progress of the project. Calculation of the 7th week BCWP of the Badegan Market Renovation Project in Ponorogo Regency, as follows:

BCWP = % realization weight x project value
      = 7.449% x IDR 3,673,751,997.30
      = IDR 273,657,786.28

The BCWP value of the 7th week is IDR. 273,657,786.28, then accumulated in the previous week, so that the value of BCWP up to the 7th week to IDR. 2,267,954,058.01.

- ACWP (*Actual Cost for Work Performed*)

The project costs required are as follows:
= Indirect costs (12.5%) + direct costs (87.5%)
= IDR 459,218,999.66+IDR 3,214,532,997.64
= IDR 3,673,751,997.30

Accelerated ACWP costs are obtained from direct costs, which amounted to IDR 3,214, 532,997.64.

The ACWP value of the 7th week is IDR 239,450,562.99, then accumulated in the previous week, so that the ACWP value until the 7th week becomes IDR 1,984,459,800.76.

The three indicators that have been calculated (BCWS, BCWP, ACWP) are accelerated to provide an overview of achieving cost and time. The relationship between the three indicators in the Badegan Market Renovation Project in Ponorogo Regency is as follows:

Table 5: Calculations Recapitulation of Accelerated BCWS, BCWP, ACWP Badegan Market Renovation of Ponorogo Regency

No	Month	Sunday	Period	Weight of the Weekly Plan	Accelerated BCWS Cumulative (IDR)	Accelerated BCWP Cumulative (IDR)	Accelerated ACWP Cumulative (IDR)
1	October	1	10 - 16	6.836	121,986,935.07	251,137,686.54	219,745,475.72
		2	17 - 23	10.847	370,534,626.45	649,629,565.68	568,425,869.97
		3	24 - 30	9.792	652,678,779.84	1,009,363,361.26	883,192,941.10
2	November	4	31 - 06	10.935	947,313,690.02	1,411,088,142.16	1,234,702,124.39
		5	07 - 13	5.604	1,523,541,690.80	1,616,965,204.09	1,414,844,553.58
		6	14 - 20	10.271	1,960,681,440.96	1,994,296,271.73	1,745,009,237.77
		7	21 - 27	7.449	2,242,237,794.03	2,267,954,058.01	1,984,459,800.76
3	December	8	28 - 04	10.922	2,523,794,147.11	2,669,201,251.16	2,335,551,094.76
		9	05 - 11	10.659	2,952,410,792.63	3,060,786,476.55	2,678,188,166.98
		10	12 - 18	10.198	3,381,027,438.16	3,435,435,705.24	3,006,006,242.08
		11	19 - 25	4.356	3,537,419,060.68	3,595,464,342.24	3,146,031,299.46
		12	26 - 28	2.131	3,673,751,99730	3,673,751,997.30	3,214,532,997.64

In table 5 the cumulative calculation of BCWS, BCWP and ACWP every week until the 7th week. The BCWS value reached IDR 2,242,237,794.03, while the BCWP value was IDR 2,267,954,058.01 and the ACWP value was IDR 1,984,459,800.76. The graph of the relationship of the three indicators is shown as Figure 3.
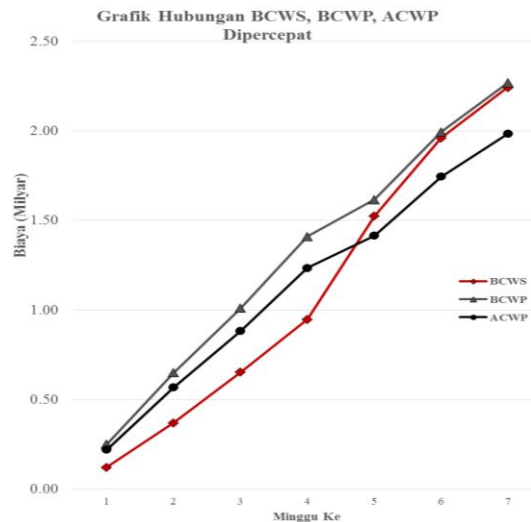
Figure 3. Relationship between Accelerated BCWS, BCWP, ACWP

From figure 3 shows at the end of week 7 looks BCWS and ACWP value smaller than the value of BCWP, which means that the actual cost is greater than the planned budget. This shows that the project has accelerated from the planned schedule, more work packages have been implemented than planned.

Calculations Based on Accelerated Cost Aspects

Earned Value Analysis seen from the aspect of cost, used Cost Variance (CV), Cost Performance Index (CPI), Estimate at Complete (EAC). Details of the calculation of these parameters are as follows:

a. *Cost Variance* (CV)

Calculation of the CV value at week 7, is as follows:

CV = BCWP – ACWP
=IDR 2,267,954,058.01–IDR 1,984,459,800.76
=IDR 283,494,257.25

From the results of the calculation of the CV in the 7th week obtained a CV value of IDR 283,494,257.25, which means the CV value is greater than 0 (CV> 0) or positive value. This shows that the costs used in the completion of the project are smaller than the planned costs.

b. *Cost Performance Index* (CPI)

Calculation of the CPI value at the 7th week, is as follows:

CPI = BCWP / ACWP
= IDR 2,267,954,058.01/IDR 1,984,459,800.76
= 1.14

Obtained a value of 1.14, this shows that the costs used in project completion are smaller than the planned costs.

c. *Estimate at Complete* (EAC)

Before determining the value of EAC (Estimate at Completion), the ETC (Estimate to Complete) is calculated first based on BAC (Budget at Completion) and BCWP (Budgeted Cost for Work Performed). Then Estimate at Completion (EAC) is calculated, the calculation is as follows:

ETC=(BAC – BCWP) / CPI
=(IDR3,673,751,997.30-IDR2,267,954,058.01) / 1.14
= IDR 1,230,073,196.88
EAC=ACWP + ETC
=IDR1,984,459,800.76 + IDR 1,230,073,196.88
=IDR 3,214,532,997.64

From the calculation results, it is estimated that the amount of costs that will be absorbed in the 7th week is IDR 3,214,532,997.64.

Calculation Based on the Accelerated Time Aspect

In analyzing the concept of Earned Value by integrating the time aspects used Schedule Variance (SV), Schedule Performance Index (SPI), Estimate All Schedule (EAS). Details of the calculation of these parameters are as follows:

a. *Schedule Variance* (SV)

Calculation of SV values in the 7th week, is as follows:

SV = BCWP – BCWS
= IDR 2,267,954,058.01–IDR 2,242,237,794.03
= IDR 25,716,263.98

From the calculation results obtained SV value of IDR 25,716,263.98. SV has a positive value indicating that the project is accelerating from the planned schedule, the work packages that are implemented are more than planned.

b. *Schedule Performance Index* (SPI)

Calculation of the SPI value at week 7, is as follows:

SPI = BCWP / BCWS
= IDR 2,267,954,058.01/IDR 2,242,237,794.03
= 1.01

From the calculation results obtained an SPI value of 1.01. This SPI value indicates that the project is accelerating. Job performance is as expected because it is able to achieve the planned work targets.

c. *Time Estimate* (TE)

TE calculation is done to determine the estimated completion of the work time, the calculation is as follows:

$$TE = ATE + \left(\frac{OD - (ATE \times SPI)}{SPI} \right)$$

6

$$TE = 49 + \left(\frac{80 - (49 \times 1.01)}{1.01} \right)$$

= 79.09

The initial planning time (Original Duration) is known for 80 days and the actual time expended (ATE) was 49 days. From the calculation of time estimate (TE), it is known that the estimated time of project completion was 79.09 days.

4. Analysis Between the CPM Method and the Earned Value Method Results

Based on the network diagram using the CPM method, the determination of the critical trajectory of the implementation of the Badegan Market renovation work in Ponorogo Regency can be completed in 80 days. The renovation work can be accelerated 40 days from the original planning of 120 calendar days, and there is no change in costs so that the work time difference can be used to evaluate and repair.

Based on the S-curve graph of planning and project realization, the percentage of work until the 7th week, because in the 7th week there was an increase in the percentage of the work volume. The actual physical percentage (realization) of the project tends to be smaller or behind schedule. Analysis of earned value is done in the 7th week.

From the cumulative result 7th week shows that the CV value of IDR 283,494,257.25 and CPI = 1.14. This shows that in carrying out the renovation work at the Badegan Market in Ponorogo Regency, the contractor received a profit or the cost incurred by the contractor was smaller than the available budget of IDR 283,494,257.25. This is reinforced by a CPI of 1.14 > 1.

From the cumulative SPI calculation results of the 7th week, the SPI value is 1.01. SPI value is positive, this means that the work is carried out exactly according to plan (on schedule) and can be accelerated. From the calculations the estimated value of the final project cost is obtained EAC of IDR 3,214,532,997.64. From the calculation of time estimate (TE), it is known that the estimated time of project completion was 79.09 days ~ 80 days.

The estimated value is known to the amount of costs that are still available on the project has been incurred for:

Remaining Funds = BCWP – ACWP
    = IDR2,267,954,058.01 – IDR1,984,459,800.76
    = IDR283,494,257.25

Thus the relationship between cost and time for carrying out renovation work in Badegan Market in Ponorogo Regency is depicted as figure 4.
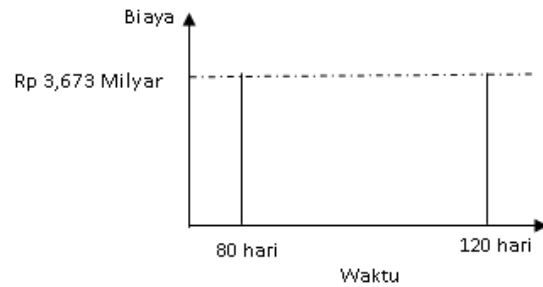

Figure 4.   Relationship Between Time and Cost of Badegan Market Renovation Work Implementation in Ponorogo Regency

CONCLUSION

CPM method is a network analysis that seeks to optimize the total cost of the project through reduction or acceleration of the total project completion time concerned. While the Earned Value Concept can be used as a performance measurement tool that integrates aspects of cost and time aspects. So using the CPM and Earned Value methods in project management is one of the effective and efficient ways in implementing project planning and controlling. Through these two methods, an effort or alternative can be seen in accelerating project performance by taking into account the least estimated cost increment in terms of total costs, the use of labor used, overhead costs, and how much work is being done acceleration and the time of its implementation [7].

From the results of the discussion of the time control mechanism with the CPM Method and the Earned Value Method in the Madegan Market Renovation Work of Ponorogo Regency, in accordance with the study objectives and the discussion results, it can be concluded that:

1. Based on Method Earned Value, project work performance of Badegan market Renovation in Ponorogo as expected, and capable achieving targets that have been planned and accelerated, the estimated time of project completion for 79.09 days.

   By using the critical path determination from the CPM Method, the time required to complete the Badegan Market Renovation Project in Ponorogo Regency is 80 calendar days (12 weeks), and can be accelerated 40 days from the original planning of 120 calendar days (17 weeks).

2. The estimated cost of the Ponorogo Regency Badegan Market Renovation project is the

same as the contract value, which is IDR 3,673,751,997.30

3. Based on *Cost Variance* (CV) value, p is no Badegan Market *Renovation* project of Ponorogo, contractors profited or the costs incurred by the contractor is smaller than the available budget in the amount of IDR 283,494,257.25

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