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Earned Value Concept as a Method to Analyze Cost and Time Control

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Abstract: The successful construction of infrastructure is dependent on many aspects, including at least time, cost, and control. With good control, deviations during the execution of work are expected to be minimized. In the case of the "MAS BIMACIKA" Service Office Building Construction project, acceleration of construction becomes an issue. Acceleration needs more resources than normal conditions, the addition of resources is required to achieve productivity value as planned. This study aimed to examine time and cost performance in the "MAS BIMACIKA" Service Office Building Construction Project. The Earned Value Concept, and the Crashing and Overlapping method used to analyze the costs resulting from the acceleration of work, were adopted in the process of controlling. Budget Cost of Work Schedule, Budget Cost of Work Performance, and Actual Cost of Work Performance were the parameters of the study. From the results of the analysis carried out until week 5, it is observed that the work could be completed earlier. This condition is indicated by the value of BCWP which is higher than BCWS. However, from the cost perspective, the construction resulted in wastage. This finding is confirmed by the value as shown in BCWP which is below ACWP. The analysis results until the 10th week show that the work could be completed earlier. This finding is indicated by the value of BCWP which is higher than BCWS. In terms of costs, the contractors still gained profit. This statement is supported by the value of ACWP which is below BCWP.

Keywords: control; earned value concept; crashing; overlapping

1. Introduction

National strategic development cannot be separated from the situation in a country. In Indonesia in particular, development in many sectors has been carried out as an effort to improve the standard of living of the people and the country's economy and to accelerate national growth to become a developed country. Through infrastructure development, the economy is expected to continuously move.

The current development has been persistently carried out by the government in supporting economic development. In the process of constructing infrastructure facilities, the government often encounters obstacles such as excessive costs, work delays, and quality that is not in accordance with the initial plan.

Infrastructure development is dependent on factors supporting success in work execution. Construction work is limited by time and cost. Therefore, control is needed. Control in the construction project is an effort to optimize all available resources in the construction work. This aims not only to ensure that the work can run as expected but also to accommodate the smooth running of the work (Soeharto, 1995).

Construction acceleration is a problem occurring in the "MAS BIMACIKA" Service Office Building Construction project. In the acceleration of work, there must be an increase in resources. This happens with the aim of increasing the value of productivity. However, acceleration often makes expenses increase resulting in an increase in the implementation costs from the initial plan. One solution to this problem is to carry out supervision. This is essential that work can be synergized between the work performed and the costs incurred.

Project control can be executed through a number of methods. One of them is through the concept of control as used in this study (Earned Value Concept). Control using the Concept of Value Results is an effort to calculate the work budget based on the cost of the completed project (Soeharto, 1995). By applying this method, it is expected that cases of irregularities potentially occurring in the work can be identified earlier. This study aims to examine the time and cost performance of the BIMACIKA MAS Service Office Building Construction Project.

Management of construction is an activity of planning, organizing, as a leader, and supervising the resources used to achieve the goals initially set. Construction management can be done with a horizontal and vertical sequential and hierarchical approach (Kerzner, 2000). Suharto (1999) defines construction management refers to the application of education, expertise, skills, and a good systematic work sequence even though it has minimal resources to achieve the goals set before to reach maximum results in terms of quality, time, cost, and safety at work.

The controlling method is a structured effort in setting a reference adjusted to the planning stage, creating an information system, and comparing the work with the quality reference used. It can then be taken to improve what is needed so that the resources can be optimally used to achieve results as targeted. Construction activities generally require a system to control quality, cost, and time, which are important to ensure that the project runs in line with indicators as earlier managed.

The controlling method using the concept of value for results is a way of assessing the amount budget. This budgeting term refers to the proportional financial planning aimed to support the work items which have been completed (Budget Cost of Work Performance) (Soeharto I., 1995). The way of controlling using this concept of the result value can be used in analyzing performance and also designing plans to achieve the goals as prearranged.

Suharto (1995) confirmed the concept of result value adopts three parameters; (1) BCWP (Budget Cost of Work Performance), (2) ACWP (Actual Cost of Work Performance), and (3) BCWS (Budget Cost of Work Schedule). Budgeted Cost of Work Performance (BCWP) is a calculation made based on work items completed within a certain period. Actual Cost of Work Performance (ACWP) is a description of all expenses paid in completing the work items at a certain time. Budget Cost of Work Schedule (BCWS) is a planned cost referring to a work plan made for a certain duration of project execution.

The use of the Result Value Concept method can also help evaluate the performance of the completed work. The use of the result value concept method in evaluating work performance is explained by various terms related to the achievement, such as Cost Variant, Cost Performance Index, Estimate at Completion, Schedule Performance Index, and Variant at Completion.

The term cost variance is the difference between the performance after the work completion and the expenditure for the work duration of the project from start to finish. Calculation of the value of the Cost Variant can be made through:

$$CV = BCWP - ACWP \quad (1)$$

The term Schedule Variant (SV) is used in calculating the deviation in the Budget Cost of Work Schedule and the Budget Cost of Work Performance. The calculation of the Schedule Variant value can be made through

$$SV = BCWP – BCWS \quad (2)$$

The variable on the budget savings can be shown by comparing the completed work items with the costs paid in the same time. The calculation of the Cost Performance Index can be done by:

$$CPI = BCWP: ACWP \quad (3)$$

Variables in the effective work can be shown through a comparison of the completed work items with the work items previously planned at the same time. Calculation of the value of the Schedule Performance Index can be made by:

$$SPI = BCWP: BCWS \quad (4)$$

The term Estimate at Completion (EAC) is a term to predict the costs incurred in completing a work. It is necessary to take into account the value of the Cost Performance Index and Schedule Performance Index useful in giving an insight into the amount of budget required to complete construction work. Calculations in Estimate at Completion can be done by:

$$EAC = ACWP + ETC \quad (5)$$

The function of accelerating work time is to complete the work before the deadline. While the maximum work time refers to the completion time of work with the shortest duration. It covers all the existing work items assuming that resources are available. In the acceleration of work, work location is an aspect of consideration.

Overlapping acceleration and shortening duration are a combination of two methods. The overlapping method is changing the order of a work item so that it can be done faster without waiting for other work, while the shortening method is a way of accelerating the duration of work by reducing the required duration so that the work can be completed faster. With this understanding, this combination of two methods becomes a strategy for accelerating the duration by making changes to the work order.

Irawan et al. (2019) mentioned budget supervision and work implementation schedules using the value concept method at the construction project of the Police Unit office of Civil Service in the regency of Majalengka were considered effective. This method helped show the work performance; It ran very fast based on the schedule. The budget paid was relatively low in accordance with the implementation cost. Using this method in budget supervision and schedule implementation, Auzan (2017) could recognize cost overruns in a construction project and predict a delay in the project completion.

Research conducted by Sigit (2019) shows that the application of the value concept method to the project of Tepuai – Nanga Semangut bridge replacement can provide an illustration that the work ran very quickly and could be completed within a predictable profit budget. Desmi (2011) suggested that the application of earned – value concept method in the time and budget monitoring during the maintenance project at the sections of Simpang Raja Bakong – Tanah Pasir could provide beneficial information; (1) the project was potentially late from the schedule, and (2) of if the expenditure was not exceeding the plan, it would have made efficiency on the budget.

Adinanta (2020) stated the application of earned–value concept in the asphalt road addition project helped identify that the project was still profitable and helped find out the duration of the project completion. Research conducted by Bhosekar (2012) shows that the value concept method is the easiest method to monitor work and evaluate projects based on the money spent. Waris (2012) shows that the value concept method is the most effective method for financial management in project construction.

Based on the previous studies it is confirmed that the earned-value concept as a method of control analysis can help provide not only real-time information, but also cost performance on the observed project. This study aims to examine time and cost performance of the building construction project of BIMACIKA MAS Service Office.

2. Method

The earned-value concept is the primary method of the study. This method is a way to calculate the work budget based on the project costs implemented (Soeharto, 1995). It serves to describe how work is completed, both in terms of time and budget.

This research was carried out through collecting data on the project for the construction of the BIMACIKA MAS service office building, in the form of weekly project reports and the S Curve used, as well as project financial reports. Weekly reports referred to the results of work which had been completed. The data from the report was then compared with the weekly plan schedule obtained from the S Curve report to find out whether the work was completed earlier or later than planned. The financial statements in this case were sorted by week order. This was important as a reference for making comparisons with the progress obtained.

The data obtained is then processed according to the concept of earned value by referring to certain parameters as predetermined, such as BCWS, BCWP, and ACWP. From the analysis, data were then used as the basis to evaluate the project performance, mainly related to deviations in time and costs. The data were then presented in the form of an overview of the project; whether it experienced waste or not, whether work could be completed more quickly, or experiencing delays.

The acceleration method used in this study belongs to the type of combination concept. This is a combination of the Crashing method and the Overlapping method. The first thing required to be done was to create a network using the Primavera application. The existing work items were then inputted into the application in order to find out which work was the priority.

The priority work can be accelerated by using a combination method. Acceleration of duration and cost requirements can be calculated through the number of additional workers, and additional working hours. With this addition, the costs required will certainly be different from the previous budget plan. With the addition of labors, it means that the level of productivity will increase so that the required duration will be smaller.

The cost calculation is based on the amount of labor needed and the work time after the acceleration. The calculation of normal wages was calculated based on the daily wages of workers on the budget plan of the project. Wages for overtime were calculated based on the Decree of the Minister of Manpower number KEP. 102/MEN/VI/2004 concerning Overtime and Overtime Wages, Article 11. The regulation states that the overtime pay for the first hour is 1.5 x $\frac{1}{173}$ x monthly wages, and the second overtime pay and the rest is 2 x $\frac{1}{173}$ x monthly wages. The total cost of wages in this accelerated method is the combination of the normal hourly wages added to the overtime pay.

After duration and cost are identified using the earned value concept method, and also the acceleration using the combination method, the next step was to conduct an analysis based on these two results with the aim of knowing the optimum results.

3. Result And Discussion

The following are data related to the study; See Table 1. for Budget Plan; See Table 2. for the list of wages of workers, See Table 3. for the number of workers.

Table 1. Budget Plan

No.	Work description	Total price (Rp)
1	Preparation	87.662.272,59
2	Earthwork	517.667.142,53
3	Foundation	804.965.459,47
4	Concrete work	1.543.796.279,24
5	Iron and Aluminum Work	1.300.409.809,54
6	Wall and Plastering Work	752.167.448,97
7	Floor Covering and Wall Covering Work	830.454.685,48
8	Ceiling Work	194.015.347,00
9	Roof Covering Work	174.363.608,56
10	Woodwork	146.433.867,50
11	Painting Work	458.744.264,87
12	Building Sanitation Work	116.155.015,50
13	Electrical Work	307.658.000,00
14	Landscape Work	84.489.361,25
15	Other Work	229.492.604,41

Source: BIMACIKA MAS Construction Project Budget Plan, 2021

Table 2. List of Wages of Workers

Types of Workers	Unit	Price
Worker	OH	90.000
Bricklayer	OH	100.000
Carpenter	OH	100.000
Blacksmith	OH	100.000
Painter	OH	100.000
Plumber	OH	100.000
Aluminum Builder	OH	100.000
Head of worker	OH	110.000
Foreman	OH	120.000

Source: Work Data of BIMACIKA MAS Construction Project, 2021

Table 3. Number of Workers

Types of Workers	Unit	Total
Worker	Person	14
Bricklayer	Person	12
Carpenter	Person	8
Blacksmith	Person	10
Head of worker	Person	2
Foreman	Person	1

Source: Work Data of BIMACIKA MAS Construction Project, 2021

The parameters used in the result value concept method include the Budget Cost of Work Schedule, Budget Cost of Work Performance, and Actual Cost of Work Performance. BCWS value is the cost required according to the progress of the weekly plan. The value of BCWS is presented in Table 4. BCWP value is the cost required to achieve the progress completed each week. See Table 5 for the value of BCWP. ACWP value is the real cost incurred for a period of each week. The value of ACWP is presented in Table 6.

Table 1. Budget Cost of Work Schedule

Week	Weight	Weekly (Rp)
1	0,077	5.837.631,09
2	0,313	23.646.281,39
3	0,333	25.177.396,98
4	3,658	276.465.489,35
5	3,834	289.760.600,23
6	3,798	287.038.403,82
7	2,811	212.429.650,45
8	3,055	230.924.834,21
9	4,521	341.723.729,25
10	4,154	313.940.119,32
11	5,577	421.544.378,03
12	8,936	675.368.143,74
13	6,036	456.169.849,35
14	2,244	169.621.132,19
15	2,325	175.692.902,16
16	1,966	148.624.585,66
17	2,162	163.408.760,52
18	2,193	165.726.997,90
19	2,156	162.970.294,19
20	1,466	110.784.872,76
21	3,859	291.657.012,21
22	4,235	320.073.982,56
23	4,017	303.620.616,16
24	3,721	281.214.364,70
25	3,851	291.052.925,00
26	5,099	385.392.855,97
27	2,852	215.581.490,31
28	2,572	194.412.688,24
29	2,742	207.237.907,20
30	2,474	186.998.343,36
31	1,727	130.545.776,18
32	0,885	66.916.311,58
33	0,338	25.511.980,85
34	0,007	504.286,75
35	0,007	504.286,75
36	0,000	0,00

Table 2. Budget Cost of Work Performance

Week	Weight	Weekly (Rp)
1	0,515	38.891.119,83
2	1,216	91.917.259,74
3	2,492	188.370.493,07
4	4,890	369.563.161,31
5	1,063	80.341.837,18
6	3,284	248.172.007,32
7	2,193	165.734.681,61
8	5,184	391.801.030,60
9	3,940	297.777.842,32
10	2,847	215.164.081,43

Table 6. Financial Report of the Work

Week	Weekly (Rp)
1	184.531.600,00
2	262.311.450,00
3	61.866.250,00
4	392.871.700,00
5	83.837.550,00
6	218.586.800,00
7	132.950.000,00
8	81.302.600,00
9	295.503.700,00
10	193.769.900,00

Source: Project Financial Report, 2021

Based on the data and the method of earned value concept, performance analysis on time performance and cost performance can be carried out. The indexes used according to the method of earned value concept include Schedule Variant, Cost Variant, Time Performance Index (SPI), and Cost Performance Index (CPI). The value of the Schedule Variant and Cost Variance indices can be seen in Table 7. While the value of time performance and the cost performance indices are presented in Table 8.

Table 7. Schedule Variant and Cost Variant Index

Week	SV (Rp)	CV (Rp)
1	33.053.488,74	(145.640.480,17)
2	68.270.978,35	(170.394.190,26)
3	163.193.096,10	126.504.243,07
4	93.097.671,96	(23.308.538,69)
5	-209.418.763,05	(3.495.712,82)
6	-38.866.396,50	29.585.207,32
7	-46.694.968,84	32.784.681,61
8	160.876.196,40	310.498.430,60
9	-43.945.886,93	2.274.142,32
10	-98.776.037,90	21.394.181,43

Table 3. SPI and CPI Index

Week	SPI	CPI
1	6,662	0,211
2	3,887	0,350
3	7,482	3,045
4	1,337	0,941
5	0,277	0,958
6	0,865	1,135
7	0,780	1,247
8	1,697	4,819
9	0,871	1,008
10	0,685	1,110

From the analysis of time performance on the construction work of BIMACIKA MAS Service Office Building based on the draft of Earned Value, it was obtained a value of 1,238, which means the work can be completed earlier than the deadline. The graph of the Budgeted Cost of Work

Performed (BCWP) from week 1 to week 5 is above the graph of the Budgeted Cost of Work Schedule (BCWS). The progress from the sixth week to the tenth week after the acceleration of the work went faster than the initial work progress plan.

From the analysis of cost performance based on the concept of the Earned Value Concept, the work was wasted from the initial expenditure plan. Larger expenditures indicate that the project was experiencing waste. This was because the service provider spent funds to buy pile materials and paid rent for the piling equipment. A lot of funds were spent but could not be progressed because the piling work items had not been carried out. The results of the analysis from week 6 to week 10 show that the work expenditures were below the progress achieved. This demonstrated that the acceleration did not burden the total project expenditure.

The scheduling method applied in this study used the Primavera application. The aim of using the application was to find jobs that were on the critical path. The critical work item would be accelerated using the Crashing method, by reducing the amount of its duration. From the analysis using Primavera, it was reported that several jobs belonged to critical work items. But not all the critical work items will crash. The work items that would be accelerated were structural work items. These were only because they were related to structural work and the completion of architectural work. See Table 9 for the work items to analyze.

Additional resources used are also taken into account in order to provide accountable results. The addition of working hours would have an impact on the value of its productivity. The thing that affected the level of worker productivity was the fatigue factor at work. The longer the additional hours of work carried out, the greater the value of productivity decline. Normal productivity levels when compared to overtime can be seen in Table 10.

Table 9. Work on the Critical Path

Work	Volume (kg)	Normal Duration (Day)
Pilecap Foundation Reinforcement	1.556,38	3
Tie Beam Reinforcement	3.810,54	7
K1 Column Reinforcement	5.702,86	13
K2 Column Reinforcement	5.522,34	12
G1 Beam Reinforcement	5.189,75	10
G2 Beam Reinforcement	4.174,01	9
B1 Beam Reinforcement	3.638,29	8
B2 Beam Reinforcement	327,71	1
B3 Beam Reinforcement	1.738,97	5
B4 Beam Reinforcement	4.199,90	10

Source: Primavera Analysis of BIMACIKA MAS Development, 2021

Table 10. Productivity of Normal and Overtime Workers

Description	Normal	1 hour overtime	2 Hours Overtime
Productivity (Kg/hour/person)	1,876	1,706	1,421
Effectiveness (%)	100	90,909	83,333
Productivity Decrease (%)	0	9,901	16,667

By taking into account the level of worker productivity when working overtime, the duration can be calculated using the Crashing and Overlapping methods. See Table 11 for detail.

Table 11. Duration of Work after Acceleration

Description	Normal Duration (days)	Duration after Acceleration (days)
Pilecap Foundation Reinforcement	3	2
Tie Beam Reinforcement	7	4
K1 Column Reinforcement	13	6
K2 Column Reinforcement	12	6
G1 Beam Reinforcement	10	6
G2 Beam Reinforcement	9	4
B1 beam reinforcement	8	4
B2 Beam Reinforcement	1	1
B3 Beam Reinforcement	5	4
B4 Beam Reinforcement	10	7

Accelerating the duration of work definitely required more resources so that the work could be completed earlier. The addition of these resources had an impact on the project expenditures. The financing of labor wages for overtime had been stated in the Decree of the Minister of Manpower number KEP. 102/MEN/VI/2004 concerning Overtime and Overtime Wages, Article 11. The recapitulation of the acceleration costs with the additional working hours is presented in Table 12.

Table 12. Recapitulation of Duration and Cost of Additional Working Hours in Critical Work

Description	Duration (Day)	Acceleration Cost (Rp)
Normal Condition Project	252	1.887.139.041,73
Crashing and overlapping	192	1.897.698.463,70

The calculation conducted above is a calculation of direct costs. The construction work costs were not only about direct costs, but also indirect costs. These indirect costs were related to the smooth running of work management. The acceleration analysis carried out resulted in an acceleration duration of 192 days from the original 252 days or 60 days faster. The recap of indirect costs due to the acceleration can be seen in the following table 4.13.

Table 13. Indirect Costs

Description	Normal Cost (Rp)	Acceleration Cost (Rp)
Project Manager	54.000.000	42.000.000
Site Manager	45.000.000	35.000.000
Executor	72.000.000	56.000.000
Logistics	31.500.000	24.500.000
Engineering Administrators	31.500.000	24.500.000
Foreman	27.000.000	21.000.000
Supervisor	22.500.000	17.500.000
Personnel Operations	36.000.000	28.000.000
Board of Directors Office Rental	22.500.000	17.500.000
Security	27.000.000	21.000.000
Rent for Personnel living place	18.000.000	14.000.000
Electricity and Water Cost	7.200.000	5.600.000
Total	**394.200.000**	**306.600.000**

4. Conclusion

Time performance according to the earned value concept method (when the work conditions reach week 10) has resulted in positive information. (1) Work can be completed earlier than scheduled and (2) positive result of both the value and the Schedule of Variance aspect, which was about Rp. 80,789,378.32. Budget performance according to the method of earned value concept at week 10 was capable of generating savings. This was indicated by the value of Cost Variance which was in a positive number, Rp. 180,201,964.41. Performance using the acceleration method of combination sped up (Crashing and Overlapping) had resulted in a duration of 192 days, 60 days faster than the previous one of 252 days. Expenses, when working conditions were accelerated using the combined acceleration method, were reported to be capable of saving costs incurred by Rp. 87,600,000.00. This acceleration method was considered capable of describing the possible duration and cost. This was different from the result value concept method which could only describe the conditions at the time of the work completion. Based on these findings, the acceleration method in this case became an effective choice.

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