Effective Performance Evaluation to Estimate Cost and Time Using Earned Value

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Abstract. The data from Badan Pusat Statistik (BPS) Indonesia, show that the development sector in the Yogyakarta region is changing rapidly, especially with the construction of new airports in the region. That demands the effectiveness and efficiency of cost and time in every construction. It requires supervision, evaluation, and performance control in the construction process. In this effort, this research discusses more detail about the calculation of construction project performance using the earned value method. This research conducted on an integrated development project consisting of malls, hotels, and apartments in Sleman, Yogyakarta. The research data collection was carried out by direct observation and analysis of supporting project data. The data obtained were processed and analysed using the accepted value method. The results of this study indicate that at the end of the review, the Schedule Performance Index (SPI) obtained a value of 0.58. Project progress in the field shows that the project has a 41.48% delay. It can see from the initially planned project of 99.06%, but at the time of review, the realisation was only 57.22%. In terms of costs, the Cost Performance Index (CPI) is 1.25. It shows that the costs incurred during the review are still less than the existing budget plan. At the end of the review period, the estimated final project costs are obtained, both direct and indirect costs. With the tendency of project performance at the time of review, the value is still less than the project budget, while the estimated time of project completion will be longer or late at around 56.52% of the planned schedule.

1. Introduction
The data from BPS Indonesia shows that the development sector in transportation, buildings, factories, and other infrastructures that support the economic sustainability of the present has increased rapidly. One of them can see from almost every corner of the city in the Yogyakarta region is undergoing construction, starting from the construction of malls or shopping centres, hotels, apartments, and other tourism support facilities.

This development process cannot separate from the management of construction projects. In construction projects, planning and control are the most basic functions in realising the success of activity in a construction project [1]. Cost and time control of the project over issues of effectiveness and efficiency can see from actual progress in the field. Effectiveness and efficiency of the cost and time of construction at the time of implementation need to be monitored, evaluated, and controlled. The uncontrol of cost and time can cause construction projects are different from the planned [2][3].

In recent years, various new approaches to management have been carried out to accurately predict project duration based on the Earned Value Management (EVM) method [4] [5]. Management of this project is an effective tool for managing project performance [6]. The earned value method is one of
the tools that can be used in project management to integrate costs and time. The concept of earned value presents three dimensions i.e., the physical completion of the project (the percent complete), the planned absorption of costs (budgeted cost), and the actual costs as well as what obtained from the costs that have incurred (earned value). Of the three dimensions, the concept of earned value can connect between cost performance and time derived from the calculation of variants of cost and time [7] [8].

Based on cost and time performance, a project manager can identify the overall performance of the project, and the work packages then predict the cost performance and project completion time, assuming that the trends occurred during reporting until the project completed. The results of the project performance evaluation can be used as preliminary information if there is an inefficient performance in project completion. Based on this initial information, management policies or changes in implementation methods can take, so that cost overruns and delays in project completion can prevent and handled adequately. The application of the concept of earned value to the project can provide a comprehensive described of the status of project performance [9].

Some previous studies explain that using Earned Value can lead to improved performance and practical excellence [10] [11]. The Earned Value technique is also able to monitor the potential for non-linear accruals from the number of incentives throughout the project [12]. In some project profiles, the earned value method can describe the planned value that will provide benefits, reliability, and accuracy of the duration shown by some concrete examples on several large projects [13].

Success in implementing Earned Value Analysis is also a combination of the design and operational aspects of the system. This framework can be used to develop Earned Value-based systems in the project environment [14]. In the Earned Value system, the prediction of Plan Value before the project starts will inform management about the performance of Earned Value and Actual Cost, thus enabling more effective proactive actions to ensure favourable performance results [15]. The results of the Earned Value analysis are complete and objective reports to evaluate the value management process that will be obtained later [16].

One area of potential for future research is an integrated model that focuses on time and cost as well as other factors such as quality of sustainability [17]. Based on information from various previous studies, the next will discuss in more detail on the direct application of Earned Value in one of the projects in Yogyakarta. It can provide real information about Earned Value calculations, especially in the construction sector.

2. Earned Value Concept

Three essential elements from some references in analysing the performance of the project based on the concept of earned value [18].

The first element is the Budgeted Cost of Work Scheduled (BCWS), or Planned Value (PV) is a budget that is allocated based on a work plan that has prepared against time. BCWS calculated from the accumulated planned budget for work in a certain period. BCWS, at the end of the project (100% completion), is called the Budget at Completion (BAC). BCWS also measures the time performance of project implementation. BCWS reflects the cumulative absorption of plan costs for each work package based on the order according to the planned schedule.

The second element is the Actual Cost of Work Performed (ACWP), or Actual Cost (AC) is a representation of the total expenditure incurred to complete the work within a specified period. ACWP can be cumulative up to the period of performance calculation or the number of expenses in a certain period.

The third element is the Budgeted Cost of Work Performed (BCWP) or Earned Value (EV), which is the value received from the completion of work during a specified period. This BCWP is called earned value (EV). This BCWP is calculated based on the accumulation of completed works. Project performance appraisal can be known based on analysis of variance, analysis of performance indexes, and analysis of estimated project completion costs.

2.1. Analysis of Variance

Cost Variance (CV) is the difference between the value obtained after completing work packages with the actual costs incurred during project implementation. Positive cost variance indicates that the value of the work packages obtained is greater than the cost incurred to work on the work packages, on the
opposite, the negative value indicates that the value of the completed work packages is lower than the 
cost already spent [19].

\[ \text{CV} = \text{BCWP} - \text{ACWP} \]

Schedule Variance (SV) is used to calculate deviations between BCWS and BCWP. Positive values 
indicate that the project work packages that implemented are more than planned, on the opposite, 
negative values indicate poor work performance because the work packages that implemented are less 
than the planned schedule [19].

\[ \text{SV} = \text{BCWP} - \text{BCWS} \]

Table 1 explains the project description about the variance analysis that consists of Schedule 
Variance and Cost Variance values.

| SV      | CV      | Description                                      |
|---------|---------|--------------------------------------------------|
| Positive| Positive| Work is carried out faster than Schedule Planned and lower costs |
| Zero    | Positive| Work is carried out on schedule and lower cost   |
| Positive| Zero    | Work is carried out faster than Schedule Planned and on budget |
| Zero    | Zero    | Work is carried out on schedule and budget       |
| Negative| Negative| Work is carried out late than schedule planned and over budget |
| Zero    | Negative| Work is carried out on schedule but over budget  |
| Negative| Zero    | Work is carried out late than schedule planned but on budget |
| Positive| Negative| Work is carried out faster than Schedule Planned but over budget |

Based on Table 1, it can see that SV value positive means that work is carried out faster than 
Schedule Planned and SV value negative means that work is carried out late than Schedule Planned. 
SV value zero means that work carried out on Schedule. CV value positive means that work is carried 
lower than budget and CV value negative means that work is carried out over budget. The CV 
value zero means that work carried out on Budget.

2.2. Performance Index Analysis

Cost Performance Index (CPI) is a cost-efficiency factor that has incurred. It is shown by comparing 
the value of physically completed work (BCWP) with costs that have incurred in the same period 
(ACWP). This CPI value shows the value obtained (relative to the overall project value) against the 
costs incurred. CPI less than one shows a low-cost performance because the costs incurred (ACWP) 
are greater than the value obtained (BCWP), or in other words, waste occurs [20].

\[ \text{CPI} = \frac{\text{BCWP}}{\text{ACWP}} \]

Schedule Performance Index (SPI) is a factor of performance efficiency in completing work. It is 
shown by comparing the value of physically completed work (BCWP) with the planned expenditure of 
costs incurred based on the work plan (BCWS). The SPI value indicates how much work can be 
completed (relative to the whole project) to the planned work unit. SPI value less than one indicates 
that job performance is not as expected because it is not able to achieve the planned work targets [20]

\[ \text{SPI} = \frac{\text{BCWP}}{\text{BCWS}} \]

Table 2 explains the project description about the Performance Index Analysis that consists of the 
Schedule Performance Index and Cost Performance Index values.

| Index | Score | Description                                      |
|-------|-------|--------------------------------------------------|
| SPI   | >1    | Project performance is faster than Schedule Planned |
|       | <1    | Project performance is late than Schedule Planned  |
|       | =1    | Project performance is on schedule               |
| CPI   | >1    | ACWP is less than the value of the work obtained (BCWP) |
|       | <1    | ACWP is more than the value of the work obtained (BCWP) |
|       | =1    | ACWP is same as the value of the work obtained (BCWP) |
Based on Table 2, it can see that SPI value more than one means that Project Performance is carried out faster than Schedule Planned and SPI value less than one means that Project Performance is carried out late than Schedule Planned. SPI value is one, it means that Project Performance carried out on Schedule. CPI value more than one means that Actual Cost is carried out less than Budget Cost and CPI value less than one means that Actual Cost is carried out more than Budget Cost. CPI value is one, it means that work carried out on Budget.

Estimate to Complete (ETC) is an estimate of the cost of remaining work, assuming that the trend of project performance is the same until the end of the project. The estimate can explain with some assumptions. The first is to assume that the remaining work costs a budget. The assumption used is the cost of remaining work within the budget, and it does not depend on performance at the time of review. The second assumption is that performance is equal to the end of the project. The assumption used is that performance at the time of review will remain until the end of the project [20].

Some approaches combine the two methods. If the percentage of work below 50% uses the formula:

$$\text{ETC} = (\text{Budget Cost} - \text{BCWP})$$

If the percentage of work above 50% uses the formula:

$$\text{ETC} = (\text{Budget Cost} - \text{BCWP}) / \text{CPI}$$

*Estimate at Completion (EAC)* is the estimated total cost at the end of the project obtained from the actual costs plus ETC [20].

$$\text{EAC} = \text{ACWP} + \text{ETC}$$

The importance of CPI and SPI is to predict the costs needed to complete a project statistically. There are many methods for predicting project completion costs (EAC). But calculations with SPI and CPI are more comfortable and faster to use.

EAC calculation is the sum of the actual costs that have incurred and the remaining costs that will be needed to complete the project. The remaining costs to be required are predicted statistically by calculating cost performance (CPI) and schedule performance (SPI). From the EAC value, it can estimate the difference between the project completion plan cost (BAC) and the cost of project completion based on the work performance that has been achieved (EAC) or variance at completion (VAC).

CPI and SPI indicators are more often used to assess project performance compared to SV and CV. CPI and SPI values are weight values that do not have dimensions so that they compared between project performance with one another. Besides, the SPI and CPI values provide a relative comparison to BCWS, which is the basis for assessing project status in terms of cost and time.

*Time Estimated (TE)* is the estimated time of project completion. The assumption used to estimate the completion time is the tendency for project performance to remain the same as at the time of review.

$$\text{TE} = \text{Actual Time Expended} + (\text{Original Duration} - (\text{Actual Time Expended} \times \text{SPI})) / \text{SPI}$$

### 3. Methodology

This research was conducted by direct observation in the field for 11 months (month 2nd until month 12th) to evaluate the performance of the project using the Earned Value method. From the observations in the field obtained data as in Table 3 below.

**Table 3. Recapitulation Data.**

| Month period | % Planned | % Realization | % Actual Cost | BCWS (IDR millions) | BCWP (IDR millions) | ACWP (IDR millions) |
|--------------|-----------|---------------|---------------|---------------------|---------------------|---------------------|
| 2            | 3.21      | 1.34          | 1.06          | 8,346               | 3,484               | 2,752               |
| 3            | 13.36     | 6.32          | 4.49          | 34,736              | 16,432              | 11,686              |
| 4            | 33.05     | 18.00         | 13.49         | 85,930              | 46,800              | 35,070              |
| 5            | 45.56     | 24.41         | 18.28         | 118,456             | 62,764              | 47,522              |
| 6            | 66.31     | 32.03         | 24.35         | 169,806             | 83,278              | 63,318              |
| 7            | 75.48     | 39.01         | 29.87         | 196,248             | 101,426             | 77,654              |
| 8            | 81.35     | 46.80         | 36.64         | 211,510             | 121,680             | 89,275              |
| 9            | 88.75     | 51.55         | 40.78         | 230,750             | 134,030             | 96,020              |
Table 4. Calculation of Variants and Performance Index.

| Month Period | SV (IDR millions) | CV (IDR millions) | SPI   | CPI  |
|--------------|-------------------|-------------------|-------|------|
| 2            | (4,862)           | 732               | 0.42  | 1.27 |
| 3            | (18,304)          | 4,746             | 0.47  | 1.41 |
| 4            | (39,130)          | 11,730            | 0.54  | 1.33 |
| 5            | (55,692)          | 15,242            | 0.53  | 1.32 |
| 6            | (86,528)          | 19,960            | 0.49  | 1.32 |
| 7            | (94,822)          | 23,772            | 0.52  | 1.31 |
| 8            | (89,830)          | 26,405            | 0.58  | 1.28 |
| 9            | (96,720)          | 28,010            | 0.58  | 1.26 |
| 10           | (103,844)         | 28,624            | 0.57  | 1.26 |
| 11           | (111,696)         | 29,200            | 0.56  | 1.26 |
| 12           | (108,784)         | 29,972            | 0.58  | 1.25 |

From Table 3 and Table 4 can describe using the graph in Figure 1 as below.
Based on figure 1 shows that the percentage of Budget Cost Work Performance and Actual Cost Work Performance is below of the Budget Cost Work Schedule. From Tabel 4 and Figure 1 can describe that the Schedule Variance in 12th month is negative, which is IDR 108,784 million, dan Cost Variance in 12th month is positive, which is IDR 29,972 million. The following is a graph of the SPI and CPI movement values during the review period based on Table 4.

**Figure 1.** The relationship among BCWS, BCWP, and ACWP in 12th Month.

From Figure 2 can describe that the CPI is above the ideal index dan the SPI is below the Ideal Index. Then the estimated value of the final cost and the total cost of project completion calculated as well as the estimated time of completion of the project as shown in Table 5.

**Figure 2.** SPI and CPI Graph in 12th Month.

**Table 5.** Analysis of Time and Cost Completion.

| Month Period | ETC (IDR millions) | EAC (IDR millions) | TE (month) |
|--------------|---------------------|--------------------|------------|
| 2            | 256,516             | 259,268            | 31         |
Cost and Time Estimation of Project Completion in the 12th Month based on a review conducted every month estimate that cost obtained which is an estimate for the remaining costs (ETC) of IDR 88,820 (millions), and an estimated total project completion cost (EAC) of IDR 207,621 (millions). The time estimate of project performance (TE) for 23 months, it means longer or will be late compared to the schedule planned that has a duration of 13 months. It can interpret that the project implementation delayed by 56.52%.

5. Conclusion

Based on the results of the analysis can be explained that at the end of the review was obtained The Schedule Performance Index (SPI) of 0.58. Project progress in the field shows that the project is experiencing 41.48% delays. It can see from the initially planned project of 99.06%, but at the time of review, the realisation was only 57.22%. In terms of cost was obtained The Cost Performance Index (CPI) of 1.25. It shows that the costs incurred are still below from the budget planned. At the end of the review period, direct and indirect costs estimated at IDR 207,620 (millions). If the tendency of project performance as at the end of the review, this cost is below the project budget or lower than the budget planned. While the estimated completion time of the project is 23 months means that it is longer or will be late than the schedule planned, which has a duration of 13 months. It can interpret that the project implementation delayed by 56.52% of the schedule planned.

References

[1] F. Rochman and H. C. Wahyuni, “Analisa Pengaruh Pengendalian Kinerja Proyek Terhadap Mutu Proyek Konstruksi Dengan Menggunakan Uji Statistika,” J. Tek. Ind., 2018.
[2] A. Mishakova, A. Vakhrushkina, V. Murgul, and T. Sazonova, “Project Control Based on a Mutual Application of Pert and Earned Value Management Methods,” Procedia Eng., vol. 165, pp. 1812–1817, 2016.
[3] P. A. de Andrade, A. Martens, and M. Vanhoucke, “Using real project schedule data to compare earned schedule and earned duration management project time forecasting capabilities,” Autom. Constr., vol. 99, no. October 2018, pp. 68–78, 2019.
[4] J. Batselier and M. Vanhoucke, “Evaluation of deterministic state-of-the-art forecasting approaches for project duration based on earned value management,” Int. J. Proj. Manag., vol. 33, no. 7, pp. 1588–1596, 2015.
[5] P. Ballesteros-Pérez, E. Sanz-Ablanedo, D. Mora-Melià, M. C. González-Cruz, J. L. Fuentes-Bargues, and E. Pellicer, “Earned Schedule min-max: Two new EVM metrics for monitoring and controlling projects,” Autom. Constr., vol. 103, no. March, pp. 279–290, 2019.
[6] H. L. Chen, W. T. Chen, and Y. L. Lin, “Earned value project management: Improving the predictive power of planned value,” Int. J. Proj. Manag., vol. 34, no. 1, pp. 22–29, 2016.
[7] R. D. H. Warburton and D. F. Cioffi, “Estimating a project’s earned and final duration,” Int. J. Proj. Manag., vol. 34, no. 8, pp. 1493–1504, 2016.
[8] D. A. Wood, “High-level integrated deterministic, stochastic and fuzzy cost-duration analysis aids project planning and monitoring, focusing on uncertainties and earned value metrics,” J.
[9] B. Susanti, M. Melisah, and I. Juliantina, “Penerapan Konsep Earned Value Pada Proyek Konstruksi Jalan Tol (Studi Kasus Ruas Jalan Tol Kayuagung - Palembang -Betung),” *J. Rekayasa Sipil*, 2019.

[10] J. Colin, A. Martens, M. Vanhoucke, and M. Wauters, “A multivariate approach for top-down project control using earned value management,” *Decis. Support Syst.*, 2015.

[11] G. Espinosa-Garza and I. Loera-Hernández, “Proposed model to improve the forecast of the planned value in the estimation of the final cost of the construction projects,” *Procedia Manuf.*, vol. 13, pp. 1011–1018, 2017.

[12] L. P. Kerkhove and M. Vanhoucke, “Extensions of earned value management: Using the earned incentive metric to improve signal quality,” *Int. J. Proj. Manag.*, 2017.

[13] R. D. H. Warburton and D. F. Cioffi, “Estimating a project’s earned and final duration,” *Int. J. Proj. Manag.*, 2016.

[14] D. Bryde, C. Unterhitzenberger, and R. Joby, “Conditions of success for earned value analysis in projects,” *Int. J. Proj. Manag.*, 2018.

[15] H. L. Chen, W. T. Chen, and Y. L. Lin, “Earned value project management: Improving the predictive power of planned value,” *Int. J. Proj. Manag.*, 2016.

[16] D. S. Christensen, “The Costs and Benefits of the Earned Value Management Process,” *J. Parametr.*, 2018.

[17] L. L. Willems and M. Vanhoucke, “Classification of articles and journals on project control and earned value management,” *Int. J. Proj. Manag.*, 2015.

[18] B. Wahab, “Penialaian Pengendalaian Biaya dan Waktu Pada Proyek Peningkatan Jalan Menggunakan Earned Value,” *Teras J.*, 2019.

[19] R. A. N, D. R. S, and F. Kistiani, “Pengendalian Biaya Dan Waktu Proyek Dengan Metode Konsep Nilai Hasil ( Earned Value ),” *J. Tek.*, 2015.

[20] K. A. B. Bombana, A. Efendi, and L. O. Sumarsiddin, “Pengendalian Waktu Dan Biaya Pada Proyek Dengan Metode Earned Value ( Studi Kasus Pembangunan Dermaga Kasipute),” *J. Ilm. Tek. Mesin*, 2015.