Implementing Three-Variance Approach for Project Time and Cost Control in a Building Construction Project (Case Study: A Project in West Java)

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Abstract. Earned Value Method (EVM) is one of project controlling methods. This method has been widely used in many projects since long time ago. However, this traditional EVM still has some shortcomings that related to time aspect, such as the use of monetary units, also the time aspect and work aspect are not measured separately. To overcome these shortcomings, several researches have been carried out and one of them is Three-Variance Approach (TVA). This paper proposed the use of EVM and TVA and compared the result from those methods. This paper also aimed to identify the strengths and problems that may arise when using TVA in a real project. The results are visualized with graphs, then be gathered into three categories; project status, forecasting, and trend. Project status determines the condition of the project in each period. Forecasting enables one to estimate the final condition of a project. The improvement of project condition from time to time can be seen in trend.

1. Introduction
Good planning and controlling need to be done to enhance the success of a project. Project performance can be measured with these indicators: cost, quality, time and safety [1]. There are a variety of methods that can be used for project control, one of them is Earned Value Method (EVM) [2]. This method has long been used as a tool for project control [3]. Problems and project status can be identified earlier and accurately with EVM, so that it can be used as a basis for improvement of the project condition [4]. However, there have been several issues related to the time aspect on EVM, such as the use of monetary units, and the misinterpretation of schedule variance [5] [6]. To overcome these issues, there have been various studies for development of EVM, and Three-Variance Approach (TVA) is one of the developments made [7] [8] [9] [10]. This paper aims to implement TVA in a real project, to compare the result from EVM and TVA, and to identify the strengths and problems that may arise when implementing TVA in a real project.

2. Literature Review

2.1. Earned Value Method (EVM)
EVM as one of project controlling methods is based on the concept of measuring the progress of the work that has been completed at a time, and evaluated by the help of the amount of budget provided for the work [11]. EVM has been used and studied in various countries such as Italy [12], India [13]...
and Indonesia [14]. EVM focuses on two aspects: cost and schedule. Calculations with EVM can be briefly seen in table 1.

Table 1. Summary of Earned Value Method

| Description of project performance | Cost                  | Schedule                  |
|-----------------------------------|-----------------------|---------------------------|
| Variance                          |                       |                           |
| CV = EV - AC                      | SV = EV - PV          |                           |
| CV < 0, over budget               | SV < 0, behind schedule|                           |
| CV = 0, on budget                 | SV = 0, on schedule   |                           |
| CV > 0, under budget              | SV > 0, ahead of schedule|                         |
| Performance Index                 |                       |                           |
| CPI = EV/AC                       | SPI = EV/PV           |                           |
| CPI < 1, over budget              | SPI < 1, behind schedule|                         |
| CPI = 1, on budget                | SPI = 1, on schedule  |                           |
| CPI > 1, under budget             | SPI > 1, ahead of schedule|                       |
| Critical Ratio                    | CPI x SPI             |                           |
| Forecast                          |                       |                           |
| ETC = EAC - AC                    | -                      |                           |
| (1) EAC = BAC/CPI                 | -                      |                           |
| (2) EAC = AC + BAC - EV           | -                      |                           |
| BAC - EV                          | -                      |                           |
| (3) EAC = AC + CPI x SPI          | -                      |                           |

*All the abbreviations used in this table can be seen in section 6 (Notation).*

EVM result can be visualized with graphs as seen in [7]. With the help of performance index, project performance can be evaluated (known as project trend) in two-dimensional graph [15]. EVM is useful and can form a basis to consider the improvement of the project [4]. However, in addition to the benefits gained, the use of EVM is also constrained by some issues, one of them is on time aspect as stated in [5] and [6]. The shortcomings are:

- SV is measured with monetary units, and it can be difficult to understand since ‘schedule’ is a term that is related to time units.
- SV = 0 is used in showing that the project has been completed, but when the project is on schedule, the value of SV is equal to zero, which leads to confusion.
- SV always converges to zero when it approaches the end of the project. When finished, SV = 0 can cast doubts whether the project is on schedule and overdue.

2.2. Three-Variance Approach

The project observations with TVA are reviewed in three aspects: cost, time, and scope (range of work). TVA also uses the Earned Time Method concept to determine the work rate. Work rate (WR) is the amount of work completed per unit of time. There are three types of work rate used in the observation process with TVA. These three work-rate are listed below:

- WRs, is scheduled average work rate between two observation points, such that the corresponding change in PV can be observed. WRs can be used to estimate ET with respect to EV at an observation time t1, within a given planned project duration.
- WRp, is planned average work rate from the beginning of the project (t0 = 0 dan PV0 = 0) to the observation point t1. WRp can also be used when the observation point t1 is within the planned project duration.
- WRm, is mean work rate of the project from beginning of the project (t0 = 0 dan PV0 = 0) to the end (t = PD and PV = BAC). WRm can be used to estimate ET at an observation point t1 once the planned project duration has been exceeded.

When the project is overdue, two artificial measures are used to analyze the data, called Artificial Planned Work (APW) and Artificial Planned Value (PV'). Table 2 shows the formulas used in TVA.
3. Research Methodology

This research takes a real construction project in West Java as an example. The analysis was done in steps as listed below:

- Literature study and project data collection
  Project data that are needed to perform the analysis are bill of quantity, master schedule, project reports (daily report, weekly report, progress report), project cost data, and variation order data.
- Data processing
  All the data that has been collected further processed into Planned Value (PV), Earned Value (EV), and Actual Cost (AC) in accordance with the periods of observation used.
- Analysis and result interpretation
  Analysis with EVM and TVA are carried out using the PV data, EV, and AC from every period of observation. Figure 1 can help show the steps of calculation using TVA.

Arrow that points to each box indicating the prerequisite data needed for each calculation. The results of calculation with EVM is then compared with results from TVA, and then visualized with graphs and tables.

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Table 2. Summary of Three-Variance Approach (Chang and Yu, 2018).^a.

| Description of project performance | Work formulas | Time formulas | Cost formulas |
|------------------------------------|---------------|---------------|---------------|
| WV = EV - PV                        | TV = ET - AT  | CV = EV - AC  |               |
| WV < 0, less work                  | TV < 0, behind schedule | CV < 0, over budget |       |
| WV = 0, same work                  | TV = 0, on schedule | CV = 0, on budget |       |
| WV > 0, more work                  | TV > 0, ahead of schedule | CV > 0, under budget |       |
| Variance                            | AT > PD       | PV = BAC + APW |               |
| -                                  | AT > PD       | ET = EV/WRM   |               |
| -                                  | or EV/WRp     | ALT = AT - PD |               |
| -                                  | -             |               |               |
| WV^* = EV - PV^*                   | WPI = EV/PV   | TPI = ET/AT   | CPI = EV/AC   |
| WPI < 1, less work                 | TPI < 1, behind schedule | CPI < 1, over budget |       |
| WPI = 1, same work                 | TPI = 1, on schedule | CPI = 1, on budget |       |
| WPI > 1, more work                 | TPI > 1, ahead of schedule | CPI > 1, under budget |       |
| WPI^* = EV/PV^*                    | AT > PD       |                | AT > PD       |
| Performance Index                  | WPI^* = EV/PV | TPI = 1, same work | CPI = 1, on budget |
| Forecast                            | ROW = BAC - EV | ETTC = (PD - ET)/TPI | ETC = (BAC - EV)/CPI |
| EWAC = BAC                          | ETAC = PD/TPI | EAC = BAC/CPI  |               |

^a All the abbreviations used in this table can be seen in section 6 (Notation).
4. Result and Discussion
Scope of work reviewed in this research is Mechanical Electrical works. The observation is performed periodically every three months. Table 3 shows the result of analysis with EVM and table 4 shows the results of analysis with TVA. The results of the calculations are then classified into three main sections. They are project status, forecasting, and trend. The classification is done to make the result more systematic. To simplify monitoring the classification, factors in the table are given colors. Red denotes project status, and green denotes forecasting. The trend is described separately with a graph that shows relationship of both cost and schedule performance index in two-dimensional graph (figure 2) and cost, time, and work performance index in three-dimensional graph (figure 7; figure 8).

Table 3. The result of analysis with Earned Value Method (1st period to 9th period)*.

| Factors | Dimension | Period |
|---------|-----------|--------|
| PV      | IDR (mil.) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| EV      | 154,43 | 3,189,79 | 14.590,00 | 14.590,00 | 14.590,00 | 14.590,00 | 14.590,00 | 14.590,00 | 14.590,00 |
| AC      | 17,63 | 453,16 | 2.917,58 | 7.440,93 | 11.195,72 | 12.684,60 | 13.493,74 | 14.158,49 | 14.590,00 |
| WRs     | 233,38 | 799,85 | 2.812,76 | 6.449,75 | 9.541,58 | 10.987,22 | 11.975,02 | 12.700,73 | 13.243,00 |
| WRp     | -215,75 | -346,68 | -11.672,42 | -7.149,07 | -3.394,28 | -1.905,40 | -1.096,26 | -431,51 | 0,00 |
| WRm     | 0,08 | 0,57 | 1,04 | 1,15 | 1,17 | 1,15 | 1,13 | 1,11 | 1,10 |
| CPI     | -136,80 | -2.736,63 | -11.672,42 | -7.149,07 | -3.394,28 | -1.905,40 | -1.096,26 | -431,51 | 0,00 |
| SPI     | 0,11 | 0,14 | 0,20 | 0,51 | 0,77 | 0,87 | 0,92 | 0,97 | 1,00 |
| EAC (1) | 193,191,64 | 25.751,79 | 14.065,86 | 12.646,53 | 12.434,37 | 12.637,66 | 12.947,90 | 13.087,81 | 13.243,00 |
| EAC (2) | 14.805,75 | 14.936,68 | 14.485,19 | 13.598,82 | 12.935,87 | 12.892,63 | 13.071,28 | 13.132,24 | 13.243,00 |
| EAC (3) | 1.690.915,25 | 176.434,63 | 59.086,44 | 18.600,25 | 13.310,40 | 12.885,57 | 13.026,94 | 13.099,60 | 13.243,00 |
| ETC (1) | 192.958,26 | 24.951,94 | 11.253,10 | 6.196,77 | 2.892,79 | 1.650,43 | 972,88 | 387,08 | 0,00 |
| ETC (2) | 14.572,37 | 14.136,84 | 11.672,42 | 7.149,07 | 3.394,28 | 1.905,40 | 972,88 | 387,08 | 0,00 |
| ETC (3) | 1.690.681,87 | 175.634,78 | 56.273,67 | 12.150,50 | 3.769,81 | 1.898,35 | 1.051,92 | 398,88 | 0,00 |
| Crit. Ratio | - | 0,01 | 0,08 | 0,21 | 0,59 | 0,90 | 1,00 | 1,04 | 1,08 | 1,10 |

* All the abbreviations used in this table can be seen in section 6 (Notation).

The EVM calculation results on table 3 gives the basic information that was provided by EVM. With only two aspects used in EVM (cost and schedule), the information given is less than TVA.
EVM can only show the estimation in cost aspect (EAC and ETC). In Figure 2, the project trend in two-dimensional graph can show the direction of the project movement from the previous period, which is, still, limited to two aspects only.

![Figure 2. Trend (EVM) in two-dimensional graph.](image)

The movement of project conditions is given different colors. While the color green indicates the project trend improves on both aspects (cost and schedule), blue indicates only one aspect improves (either cost or schedule). In contrast, the color red indicates the trend deteriorates in both aspects. The TVA calculation results can be seen in table 4.

| Factors | Dimension | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|---------|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| PV      | IDR (mil.) | 154,43 | 3,189,79 | 14,590,00 | -   | -   | -   | -   | -   | -   |
| ALT     | month     | -    | -    | -    | 3,00 | 6,00 | 9,00 | 12,00 | 15,00 | 17,00 |
| PV      | IDR (mil.) | -   | -    | -    | 19,453,33 | 24,316,67 | 29,180,00 | 34,043,33 | 38,906,67 | 42,148,89 |
| EV      | IDR (mil.) | 17,63 | 453,16 | 2,917,58 | 7,440,93 | 11,195,72 | 12,684,60 | 13,493,74 | 14,158,49 | 14,590,00 |
| AC      | IDR (mil.) | 233,38 | 799,85 | 2,812,76 | 6,449,75 | 9,541,58 | 10,987,22 | 11,975,02 | 12,700,73 | 13,243,00 |
| WV      | IDR (mil.) | -136,80 | -2,736,63 | -11,672,42 | -7,149,07 | -3,394,28 | -1,905,40 | -1,096,26 | -431,51 | 0,00 |
| WPI     | -         | 0,11 | 0,14 | 0,20 | 0,51 | 0,77 | 0,87 | 0,92 | 0,97 | 1,00 |
| ROW     | IDR (mil.) | 14,572,37 | 14,136,84 | 11,672,42 | 7,149,07 | 3,394,28 | 1,905,40 | 1,096,26 | 431,51 | 0,00 |
| PCR     | -         | 0,01 | 0,22 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| WCR     | -         | 0,00 | 0,03 | 0,20 | 0,51 | 0,77 | 0,87 | 0,92 | 0,97 | 1,00 |
| WRs     | IDR (mil./mo.) | 51,48 | 1,011,79 | 3,800,07 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 |
| ETs     | month     | 0,34 | 3,30 | 5,93 | 4,59 | 6,91 | 7,82 | 8,32 | 8,73 | 9,00 |
| TVs     | month     | -2,66 | -2,70 | -3,07 | -7,41 | -8,09 | -10,18 | -12,68 | -15,27 | -17,00 |
| TPIs    | -         | 0,11 | 0,55 | 0,66 | 0,38 | 0,46 | 0,43 | 0,40 | 0,36 | 0,35 |
| ETACs   | month     | 78,86 | 16,39 | 13,66 | 23,53 | 19,55 | 20,70 | 22,71 | 24,73 | 26,00 |
| ETTCs   | month     | 75,86 | 10,39 | 4,66 | 11,53 | 4,55 | 2,70 | 1,71 | 0,73 | 0,00 |
| WRp     | IDR (mil./mo.) | 51,48 | 531,63 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 |
| ETp     | month     | 0,34 | 0,85 | 1,80 | 4,59 | 6,91 | 7,82 | 8,32 | 8,73 | 9,00 |
| TVp     | month     | -2,66 | -5,15 | -7,20 | -7,41 | -8,09 | -10,18 | -12,68 | -15,27 | -17,00 |
| TPIp    | -         | 0,11 | 0,14 | 0,20 | 0,38 | 0,46 | 0,43 | 0,40 | 0,36 | 0,35 |
| ETACp   | month     | 78,86 | 63,35 | 45,01 | 23,53 | 19,55 | 20,70 | 22,71 | 24,73 | 26,00 |
| ETTCp   | month     | 75,86 | 57,35 | 36,01 | 11,53 | 4,55 | 2,70 | 1,71 | 0,73 | 0,00 |
| CV      | IDR (mil.) | -215,75 | -346,68 | 3,800,07 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 | 1,621,11 |
| CPI     | -         | 0,08 | 0,57 | 1,04 | 1,15 | 1,17 | 1,15 | 1,13 | 1,11 | 1,10 |
| ETC     | IDR (mil.) | 192,958,26 | 24,951,94 | 11,253,10 | 6,196,77 | 2,892,79 | 1,650,43 | 972,88 | 387,08 | 0,00 |
| EAC     | IDR (mil.) | 193,191,64 | 25,751,79 | 14,065,86 | 12,646,53 | 12,434,37 | 12,637,66 | 12,947,90 | 13,087,81 | 13,243,00 |

All the abbreviations used in this table can be seen in section 6 (Notation).
From the TVA results in Table 4, it can be seen that TVA provides more information than traditional EVM. TVA gives its users information in three aspects, namely cost, time, and work. Information about the work that has been completed at one particular time can be measured in the work aspect, while time aspect only focuses on monitoring the completion time of works in the project. The information provided on the cost aspect is in no way different from the traditional EVM. The use of work rate concept (WRs, WRs, and WRM) can deliver information about the value of work on each period based on the PV data. In TVA, there are cost estimation (EAC and ETC) and also time estimation: ETAC and ETTC. Figure 3 to Figure 6 show the result of TVA if displayed in a cartesian graph.

Figure 3. Result from Three-Variance Approach (a) Cost Variance (b) Cost Performance Index

Figure 4. Result from Three-Variance Approach (a) Work Variance (b) Work Performance Index

Figure 5. Result from Three-Variance Approach (a) Time Variance (b) Time Performance Index
In Figure 3 to Figure 5, if the calculation results are above the red line, then the project status in the observed aspect is in good condition. On the contrary, if the calculation results are below the line, then the aspect is monitored in bad condition. By using TVA, the separation between the work and time aspects can be clearly seen at the end of the project. In Figure 4, when the project is finished, the variance line moves towards 0, and the performance index moves towards 1, indicating that the work is completed (regardless of the project on schedule or behind schedule). At the end of the project as in figure 5, the graph deviates from the center of the X axis. The deviation of the graph shows whether the project finished ahead or behind the schedule. The line on the graph of the time aspect in Figure 5 will only be at the center of the X axis if the project is right on schedule.

Figure 6 shows the estimation result using TVA, which is estimation on the cost aspect and time aspect. With TVA, the estimation of how much time needed until the project is completed in every observation period can be known. In the last observation period, the calculation result shows a number of duration that is exactly the same as the actual project duration.

![Figure 6](image)

**Figure 6.** The graphic of time and cost forecasting from Three-Variance Approach

The project trend in TVA can be seen in three-dimensional graph as seen in Figure 7 and Figure 8. There are two different graphs, because there are two types of TPI used. The lines on the graph are given different colors to indicate the condition of the project in each period, which is improved or deteriorated, either in one aspect or all the three aspects (same as the colors used in figure 2).

![Figure 7](image)

**Figure 7.** Trend from Three-Variance Approach with TPIp
It is difficult to see the 3D graph especially when the graphs are printed. Therefore, the displacement vector is calculated to help interpret the 3D graph. Table 5 shows the result of displacement vector (The example on table 5 uses TPIP).

**Table 5.** Vector analysis in three-dimension trend

| Period | x | y | z | Vector | Description |
|-------|---|---|---|--------|-------------|
| 1     | 0,08 | 0,11 | 0,11 |        |             |
| 2     | 0,57 | 0,14 | 0,14 | 0,49   | 0,03 0,03  better  better  better |
| 3     | 1,04 | 0,20 | 0,20 | 0,47   | 0,06 0,06  better  better  better |
| 4     | 1,15 | 0,38 | 0,51 | 0,12   | 0,18 0,31  better  better  better |
| 5     | 1,17 | 0,46 | 0,77 | 0,02   | 0,08 0,26  better  better  better |
| 6     | 1,15 | 0,43 | 0,87 | -0,02  | -0,03 0,10 worse  worse  better |
| 7     | 1,13 | 0,40 | 0,92 | -0,03  | -0,04 0,06 worse  worse  better |
| 8     | 1,11 | 0,36 | 0,97 | -0,01  | -0,03 0,05 worse  worse  better |
| 9     | 1,10 | 0,35 | 1,00 | -0,01  | -0,02 0,03 worse  worse  better |

With the concept of vector, all the displacement vectors in each period can be found. If previous period is represented by \( \vec{a} \) \((x_1, y_1, z_1)\) and current period is represented by \( \vec{b} \) \((x_2, y_2, z_2)\), then the displacement vector, showing the project trend, is \( \vec{c} \) \((x_2-x_1, y_2-y_1, z_2-z_1)\). If \( \vec{c} \) is positive, the project trend is getting better, otherwise if \( \vec{c} \) is negative, the project trend is getting worse.

5. **Conclusion**

Based on the research conducted, Three-Variance Approach (TVA) as a development from Earned Value Method (EVM) can be used to control project time and project cost. Time and work that measured separately in TVA can give more details on every aspect. TVA analysis results are classified into project status, forecasting, and trend, so that the result can be more systematic. Project status and forecasting can be visualized in two-dimensional graph to make the project reports more understandable. Trend can be seen in three-dimensional graph. Three-dimensional graph readings are assisted with the concept of displacement vectors. With the help of vector concept, it is easier to read the three-dimensional graphs when the graphs are printed. It is recommended for further studies to develop a software to conduct TVA analysis, thus simplifying users in working on this new method.

6. **Notation**

The following symbols are used in this paper:

AC = Actual Cost
AT = Actual Time
ALT = Accumulated Lagged Time
APW = Artificial Planned Work
BAC = Budget at Completion
CV = Cost Variance
CPI = Cost Performance Index
ET = Earned Time
EV = Earned Value
EAC = Estimate at Completion
EVM = Earned Value Method
ETC = Estimate to Complete
ETAC = Estimated Time at Completion
ETTC = Estimated Time to Complete
EWAC = Estimated Work at Completion
PD = Planned Duration
PV = Planned Value
PV’ = Artificial Planned Value
PCR = Planned Completion Rate
ROW = Rest of Work
SV = Schedule Variance
SPI = Schedule Performance Index
TV = Time Variance
TPI = Time Performance Index
TVA = Three-Variance Approach
WR = Work Rate
WV = Work Variance
WCR = Work Completion Rate
WPI = Work Performance Index

References
[1] Husen A 2011 Manajemen Proyek Perencanaan, Penjadwalan, dan Pengendalian Proyek (Edisi Revisi) (Yogyakarta: Andi)
[2] Project Management Institute 2013 A Guide to the Project Management Body of Knowledge 5th Edition (Pennsylvania: Newtown Square)
[3] Fleming Q W and Koppelman J M 1997 Earned value project management Cost Eng. 39(2) 13–15
[4] Kerzner H 2009 Project Management: A System Approach to Planning, Scheduling, and Controlling 10th Edition (New Jersey: Wiley)
[5] Lipke W 2003 Schedule is different Measurable News 31(1) 1-10
[6] Vanhoucke M and Vandevoorde S 2007 A simulation and evaluation of earned value metrics to forecast the project duration J. Oper. Res. Soc. 58(10) 1361-74
[7] Anbari F T 2003 Earned value project management method and extensions Proj. Manage. J. 34(4) 12-23
[8] Jacob D 2003 Forecasting project schedule completion with earned value metrics Measurable News 1(11) 7-9
[9] Khamooshi H and Golafshani H 2013 EDM: Earned Duration Management, a new approach to schedule performance management and measurement” Int. J. Proj. Manag. http://dx.doi.org/1016/j.ijproman.2013.11.002
[10] Chang C J and Yu S W 2018 Three-variance approach for updating earned value management J. of Const. Eng. Manage. 144(6) 04018045 1-10
[11] Widiasanti I and Lenggogeni 2013 Manajemen Konstruksi (Bandung: Rosda)
[12] De Marco A and Narbaev T 2013 Earned value-based performance monitoring of facility construction projects J. of Facilities Manage. 11(1) 69-80

[13] Nagaraj B, Brijbhushan S, and Maneeth P D 2017 Scheduling, monitoring and cost analysis by earned value method of phase-2 (reach-2a from pier No. 443 to pier No. 470) using Primavera P6 Int. J. of Eng. Development and Research 5(3) 625-32

[14] Sediyanto and Hidayat A 2017 Analisa kinerja biaya dan waktu pada pelaksanaan proyek konstruksi dengan metode earned value (studi kasus proyek konstruksi mall dan hotel X di Pekanbaru) Jurnal Ilmu Teknik dan Komputer 1(1) 36-51

[15] Oberlender G D 2000 Project Management for Engineering and Construction 2nd Edition (USA: McGraw Hill)