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# **The Innovation Breakthrough in Digital and Disruptive Era**

# A Guideline of Earned Value Method (EVM) Implementation as Decision Baseline on Acceleration Solutions for Construction Project Scheduling

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**Abstract.** Implementing an efficient performance monitoring system is necessary to complete a facility building project on time, on budget, and by established standards and specifications. Inappropriate system monitoring process could lead to project failures such as delay which commonly occurs. If the delay happens, it is necessary to accelerate work productivity to overcome it. Earned value method (EVM) is one of the suggested global standards for measuring project performance. It effectively combines scope, cost, and schedule metrics and can provide a clear picture of the state of the project as of the control date. It also predicts the time prolong and completion budget. This paper proposes a guideline to implement EVM as a decision baseline on acceleration solutions for construction project scheduling by conducting an article review, since the EVM can predict the project’s time estimates at completion (TE). According to the guideline, when arranging network planning based on construction actual work performed, it is essential to use TE as the completion time. From the critical activities in network planning, contractors can conduct the acceleration process such as additional work hours (overtime) and additional manpower. This acceleration scenario later could be implemented in the project as the solution to overcome the delay.

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## 1 Introduction

The construction project consists of several activities that employ resources such as money, materials, manpower, and machine by a set completion date. It also typically has many parties involved and highly difficult circumstances while being executed. Hence, delay commonly occurs and leads to increase in its completed duration. According to Kamandang and Casita [1], delays in construction projects can be divided into excusable and non-excusable delays, critical and non-critical delays, and concurrent delays where these must be anticipated to perform a successful construction project management.

In managing a construction project from start to finish, strong and accurate project management is necessary [2] with the main purpose is to complete a facility building project on time, on budget, and by established standards and specifications [3] Furthermore, without an efficient performance monitoring system, it would be impossible to manage the construction process effectively enough to meet that goal [4]. According to PMBOK [2] the suggested global standard for measuring project performance is the Earned Value Method (EVM). The method effectively combines schedule metrics, and scope, cost, and can provide a clear picture of the state of the project as of the control date. Numerous authors [5–8] have discussed the idea of integrating EVM into building project cost control and even overall performance measurement. Besides, the EVM is also able to predict the time prolong and completion budget.

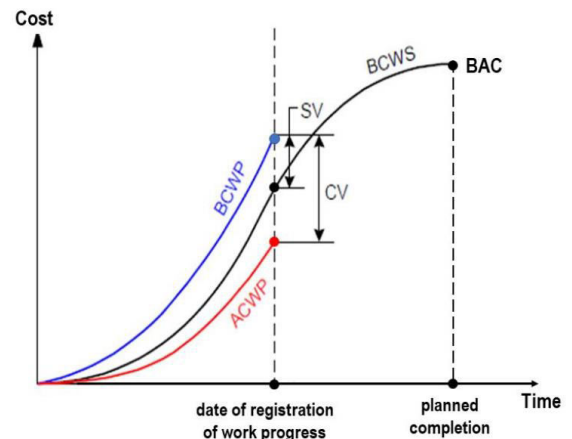
Since the delay commonly occurs in construction projects, the parties must prepare various scenarios to overcome it. One of the scenarios that manageable to perform during the project execution is activity acceleration which normally, is being focused on the critical activities to affect the total duration. This paper discusses the possibility of the implementation of EVM as a decision baseline to choose suitable acceleration solutions by conducting an article review.

## 2 Earned Value Method (EVM)

Earned value method (EVM) is one of the project management techniques which integrates scope, cost, and schedule and might capture a precise picture of the current project status at the time of monitoring [9]. It compares the work performed of the scheduled and the actual costs against the as-planned schedule and budget plan [10]. In addition, EVM according to Naderpour and Mofid [11] EVM is a well-known approach that integrates cost and schedule with quantitative measurements of project performance. It is also acknowledged that it benefits the project team by providing a visual representation of the project status and an early warning signal of whether the project is running late or over budget [12–14]. Almeida et al., [15] also stated that with the help of a quantitative method that monitors intended value, earned value, and real cost, EVM is able to assess the project's performance and forecast its outcomes.

### 1.1 EVM terminologies

EVM depends on three fundamental indicators, namely Budgeted Cost of Work Scheduled (BCWS) or Planned Value (PV), Budgeted Cost of Work Performed (BCWP) or Earned Value (EV), and Actual Cost of Work Performed (ACWP) that produce variance both in cost and schedule as follows [9,16].



**Fig. 1.** The principle of EVM [9].

The BCWS or PV is budgeted cost for the work scheduled to be executed at a particular time which is obtained from the S-curve. It is calculated at the project's planning stage which also serves as a baseline with the final cost namely BAC (Budget at Completion) [4].

The BCWP or EV is the budgeted sum of the work completed on the scheduled activity during a given time. It establishes a connection between the project's or activity's initial estimated costs and the team's current pace of completion [17].

The ACWP is defined as the real cost of performed activity during a given time. This cost is the actual cost spent by the contractor and is sometimes confidential [18].

### 1.2 Derived performance indicators in EVM

As stated before, EVM can provide an early warning signal of whether the project is behind schedule or over budget which this signal is produced by the performance indicators. At least there are four performance indicators; cost variance (CV), schedule variance (SV), cost performance index (CPI), and schedule performance index (SPI).

CV is the difference values between BCWP and ACWP.

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

SV is the difference values between BCWP and BCWS.

$$SV = BCWP - BCWS \quad (2)$$

The project is overbudget if the cost value is negative, and the project is behind schedule if the

schedule variance is positive. If the results show positive value, it means that the project is under budget and ahead of schedule.

The CPI is an index that measures how effectively the project's resources are being used. It is employed to monitor project expenses and foresee cost overruns. It is frequently used to monitor cost-effectiveness.

$$CPI = \frac{BCWP}{ACWP} \quad (3)$$

When CPI is less than 1.0, it means that the project's costs are higher than anticipated for the work completed and that the project's resources are not being used effectively. If CPI is 1, the project would be finished for the budgeted price. When CPI is greater than 1.0, the project's cost is less than anticipated given the work completed, and the project is using its resources effectively [19].

The SPI is an index that demonstrates how effectively time was spent on the project. It is used to forecast the project's estimate at completion (EAC) and project completion time. The proportion of BCWP to BCWS is referred to as SPI. If SPI is less than 1.0, it means that the project's time is not being used as effectively as it could be. That indicates that the project is running late. If SPI is 1.0, the project will be finished on schedule. When SPI is more than 1.0, the project is ahead of schedule and is effectively using the time allotted to it [20].

$$SPI = \frac{BCWP}{BCWS} \quad (4)$$

### 1.3 Forecasting indicators

Based on the actual performance, forecasting indicators can predict the cost and schedule of project at its completion [21]. The common forecasting indications are estimate to complete (ETC), estimate at completion (EAC), and time estimate (TE).

ETC is the foresee of the remaining cost that contractors need to complete the project starting from the monitoring time.

$$ETC = \frac{(BAC - BCWP)}{CPI} \quad (5)$$

EAC is the foresee of total cost that contractors need when the project is finish.

$$EAC = ACWP + ETC \quad (6)$$

TE is the foresee of project completion duration.

$$TE = ATE + \frac{OD - (ATE \times SPI)}{SPI} \quad (7)$$

where ATE is the actual duration of completed works (on monitoring time) and OD is the planned project completion duration.

## 2 Project Scheduling Acceleration

### 2.1 Critical path method (CPM)

It might be challenging to estimate the precise total duration of project operations in real-world applications. Activity durations are determined by expert estimates and opinions, but estimates from various experts on the same project may differ. Critical path method (CPM) is a helpful approach for indicating the project's total duration by considering its activities' relationship in terms of their start and finish. This approach seeks to determine the critical path (CP) in network planning that must be taken to complete the project within the allotted time frame and investigate potential alternatives if the durations of the activities change [22]. In the process of CPM, slack or float is a valuable unit that must be identified to indicate the critical activities. Slack can be defined as the activity's permitted time to delay, so when an activity has no slack, it will be categorized as critical. These sequence activities later will be referred to as critical path (CP) [23,24]. Any delay or acceleration in these critical activities will cause the overall project.

### 2.2 Crashing Project

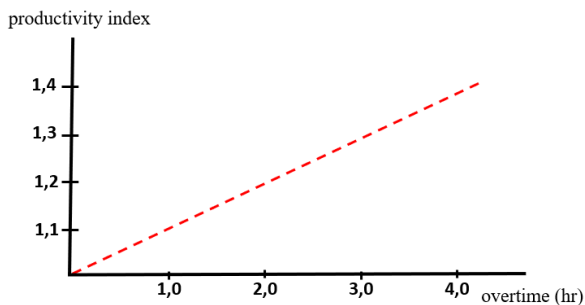
Crashing projects can be defined as the acceleration process of the project period [Click or tap here to enter text.](#) [22,24] This method reduces the amount of time needed for a project in a structured and logical approach [25]. The objective of this approach is to cost-effectively optimize the project activities' duration. A shorter length of the project activities is obtained at an additional cost using the method, which refers to a trade-off between time and cost. This expense is brought on by the increase in productivity that shortens the project's total duration. By reducing the time given to activities on the critical path, the usage of the crashing approach can drastically reduce project delays. The cost slope, which this method uses, is the extra expense incurred when project completion time is shortened [26]. Furthermore, crashing involves the addition of construction project resources to perform its process.

Based on previous research, the common crashing project in this industry is additional work hours (overtime), additional manpower, additional work shifts, and additional machines. These three kinds of additions have been implemented in numerous cases [24], [26–34]. where some of them also combined several alternative additions to one case to find the most valuable and effective one. This paper will discuss two of them; additional work hours (overtime) and additional manpower.

#### 2.2.1 Additional work hours (overtime)

Increasing the number of hours that workers and heavy equipment are required to work (overtime) is one strategy to accelerate the project's completion time. Depending on how much extra time is needed, additional working hours (overtime) can be added in increments of 1 hour, 2 hours, 3 hours, and 4 hours. The more overtime hours added, the less productive

workers may be. Figure 2 shows a sign of declining worker productivity in terms of additional working hours (overtime). The difference in the value of the productivity index due to overtime work is 0.1 per hour or a decrease in the productivity index of 0.1 per hour.



**Fig. 2.** Graphic indication of decreased productivity due to overtime work [35].

To calculate crash project due to additional works hours, some equations can be followed as below [36].

$$\text{daily productivity} = \frac{\text{work volume}}{\text{planned duration}} \quad (8)$$

$$\text{productivity per hour} = \frac{\text{daily productivity}}{\text{work duration in a day (hour)}} \quad (9)$$

$$\text{daily productivity after crashing} = (\text{work hours in a day} \times \text{productivity per hour}) + (a \times b \times \text{productivity per hour}) \quad (10)$$

where a is the number of overtime work in hours and b is decreased productivity index. For example, if the contractor wants to add 1 hour of overtime work, the productivity index will decrease to 0,1 and lead to 90% of work performance.

$$\text{crash duration} = \frac{\text{volume}}{\text{daily productivity after crashing}} \quad (11)$$

### 2.2.2 Additional number of manpower

Construction projects consist of complicated activities that are executed by following their sequences and sometimes, those are concurrent. Therefore, the availability of workspace must be considered wisely if the number of manpower wants to be increased. Besides that, it is necessary to identify the most influencing manpower in activity by analyzing the manpower productivity index. The calculation of this type of addition is by implementing equations as follows [29].

$$\text{normal number of manpower} = \frac{\text{manpower productivity index} \times \text{work volume}}{\text{normal duration (day)}} \quad (12)$$

$$\text{accelerated number of manpower} = \frac{\text{manpower productivity index} \times \text{work volume}}{\text{accelerated duration (day)}} \quad (13)$$

### 2.2.3 Crash Cost

The decision to perform an acceleration process to project scheduling will affect its cost. Based on the Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia Number KEP. 102/MEN/VI/2004, the pay for overtime work varies. In the first hour of overtime pay, employees (manpower) receive 1.5 times their regular hourly income, and in the following additional working hours, they receive 2 times their regular hourly rate [37]. The calculation for the additional cost of manpower due to overtime hours can be formulated as follows.

$$\text{normal manpower wages per day} = \text{daily productivity} \times \text{unit price of manpower wages} \quad (14)$$

$$\text{normal manpower wages per hour} = \text{productivity per hour} \times \text{unit price of manpower wages} \quad (15)$$

$$\begin{aligned} \text{overtime cost} &= (1,5 \times \text{normal hourly wages for the first additional hours} \\ &\quad \text{worked (overtime)}) + (2 \times n \times \text{normal hourly wages} \\ &\quad \text{for the next additional hours of work (overtime)}) \end{aligned} \quad (16)$$

where n is the total of additional work hours (overtime). The crash cost of manpower per day will be calculated using the equation below [38].

$$\begin{aligned} \text{crash cost of manpower per day} &= (\text{number of workhour per day} \times \\ &\quad \text{normal cost of manpower}) + (n \times \text{overtime cost per hour}) \end{aligned} \quad (17)$$

$$\text{cost slope} = \frac{\text{crash cost} \times \text{normal cost}}{\text{normal duration (in days)} - \text{crash duration}} \quad (18)$$

The normal cost of work per day is by the unit price for each region. Calculations for additional costs due to additional manpower can be formulated as follows:

$$\text{cost of adding manpower} = \text{number of manpower} \times \text{normal manpower wages in a day} \quad (19)$$

$$\text{crash cost of manpower} = \text{total cost of accelerated manpower} - \text{normal total cost of manpower} \quad (20)$$

## 3 Proposed Guideline

Based on a literature review discussed in the previous section, a guideline of earned value method (EVM) implementation as a decision baseline on acceleration solutions for construction project scheduling is proposed as can be seen in Fig 3.

The guideline is divided into two parts, the EVM and the crashing project. It also provides the needed data for both parts. The first part is the EVM which users can implement this method to their cases and evaluate the project performance and obtain the

predicted project's completed time estimate (TE). Due to this TE result and actual work performed, network planning will be arranged. According to Kamandang [39], the critical path (and its critical activities) could be changed if the project is delayed, so it is essential to arrange network planning based on the actual work performed.

In the process of arranging network planning before performing the crashing project, synchronizing the total duration of the network planning according to the TE results is crucial, because, in the previous section, the predicted delay duration has already calculated by the EVM. We might state that the TE is the project's completion time. After that, project crashing can be conducted to the critical activities.

The proposed guideline only discussed two potential acceleration processes or crashing projects, namely additional work hours (overtime) and additional manpower, but it is clearly stated before that there are others. Users might select the appropriate ones or combine them during the process. After that, to determine if there is a delay or not, network planning must be arranged once the project has crashed. Later, based on the final result user which is the contractor could implement it in their project.

## 4 Conclusion

In managing a construction project from start to finish, strong and accurate project management is necessary, with the main purpose is to complete a facility building project on time, on budget, and by established standards and specifications. The suggested global standard for measuring project performance is the Earned Value Method (EVM). The method effectively combines scope, cost, and schedule metrics and can provide a clear picture of the state of the project as of the control date. the EVM is also able to predict the time prolong (delay) and completion budget.

Since the delay commonly occurs in construction projects, the parties must prepare various scenarios to overcome it. One of the scenarios that is manageable to perform during the project execution is activity acceleration. This paper proposes a guideline to implement earned value method (EVM) as decision baseline on acceleration solutions for construction project scheduling since the EVM able to predict the project's time prolong (time estimates or TE). Later, when arranging network planning based on construction actual work performed, the TE result will be used as the completion time. From the critical activities in network planning, contractors can conduct the acceleration process (crashing program) such as additional work hour (overtime) and additional number of manpower. This acceleration scenario later could be implemented to project as the solution to overcome the delay.

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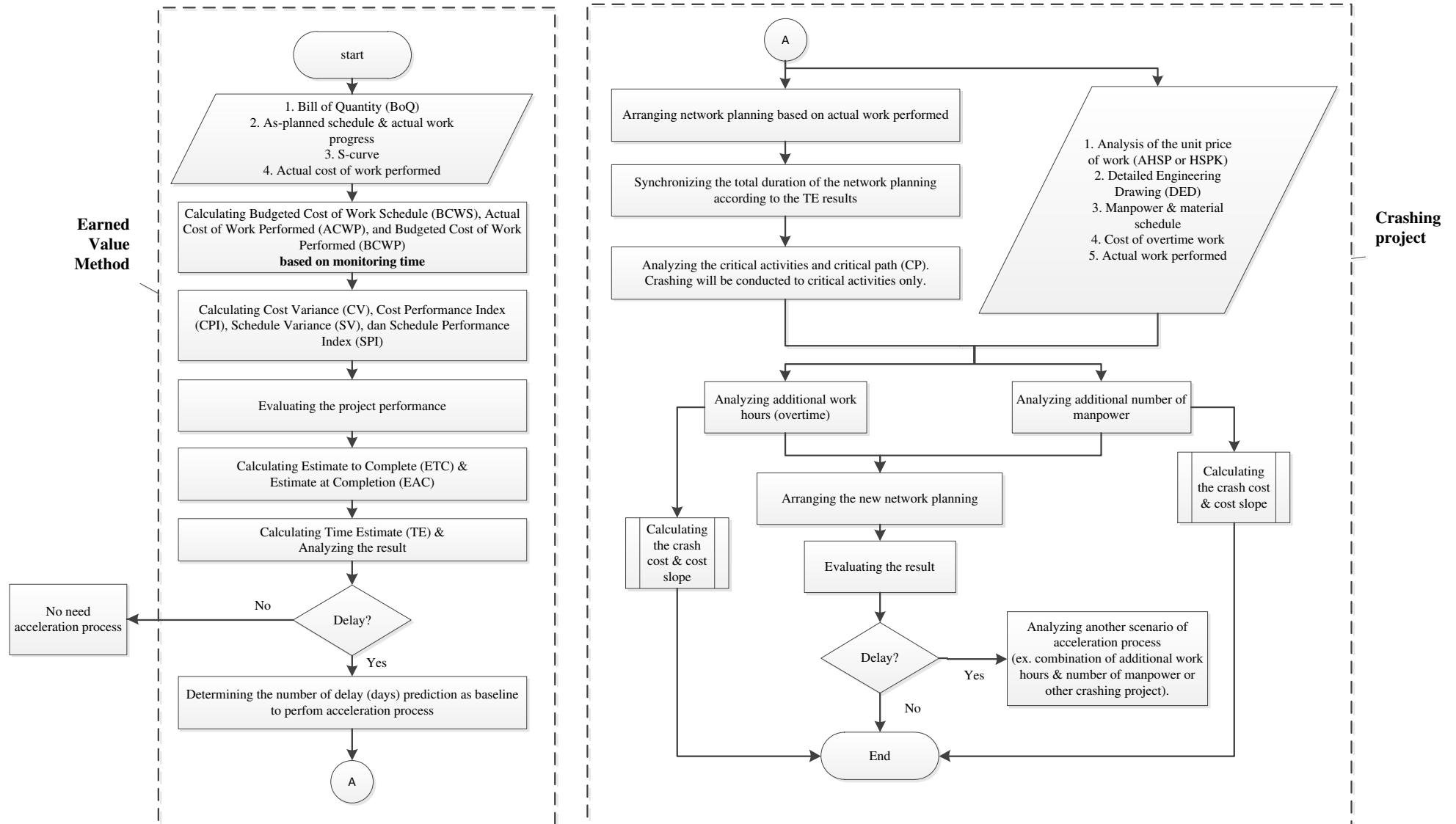


Fig. 3. Proposed guideline of earned value method (EVM) implementation as decision baseline on acceleration solutions for construction project scheduling

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