Applying Earned Value to Construction Projects

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Abstract. Construction projects are increasingly expanding and being more complex over the time, which needs special requirements at every stage of the life cycle of projects. Each project has specific characteristics and requirements that distinguish from others. The responsibilities and tasks of the parties which, involved in the project (the employer, the designer and the contractor) at each stage vary according to the projects and the implementation methods. The follow up and control of costs during implementation is one of the duties of the engineering department to know the real costs resulting from the implementation of the work. Therefore, the process of controlling costs is a continuous and substantial process, and it indicates the efficiency and success of management. EVM "earned value management is one of the tools which is used to track the progress of work performance in projects. It can indicates the deviations and variances in cost and time schedule of the projects in this research EVM was applied on a project of an administrative building. The application, which was on a specific status date, showed that this method is applicable to track the progress of the project performance, and gave a logical results that used to understand the tendency of work performance, also to predict the future performance.

1. Introduction

Earned Value "EV" analysis is an important method that measures the implementation of a project. It is one of the program management techniques that adopts "work in progress" to find what will happen to the project in the future. Its idea based on comparing actual work executed verses to a baseline planed work. It helps in establishing standards to evaluate project performance, also to control the constraints for the time and cost, in addition to identify the critical activities that may need to be adjusted during the future progressing of the project [1]. The Earned Value management method (EVM) is one of the most common methods that used for monitoring and controlling the progress work of projects. It seeks to measure the project's progress, also to predict project's total cost and finish date. It may indirectly be used to control the risks that may face the projects, in terms of failure because of exceeding the planned budget or duration of projects. The EVM can be described as an analysis that based on several specific measurements and appropriate indicators. Those measurements are taken at regular periods to follow the tendency and the variations of those indicators [2]. EVM is adopted to use in managing projects to efficiently tracking the physical achievement of specific work. The analysis of earned value can offer a possibility to understand performances of projects in the early phases of project execution, to indicate the needs to correct the performance path [3].

Agata Czarnigowska [4], defined the Earned Value as a project management technique uses the cost, the schedule and the work performance to identify the current status of a project. This technique allows the manager to read the current tendency and then to predict their possible final effect. She concluded that although this method based on simplifying the model of the project, but it has been assured as a useful practice of cost control.

(Carmen Gasparotti et al) [3], considered "Earned value management" (EVM) as a technique used to evaluate project performance in several fields, but it has been especially adopted in project management to track objectively the work performance. It offers possibility of managing project performances at the earlier stages of project, then pointing out the need to corrective action.

(Marzouk M., and Hisham M.) [5], have considered the Earned Value almost the common technique for performance measuring, which integrates the scope, the schedule, and the cost in one system. It also
measures the implementation of projects in cash terms. The technique's basic idea is to apply the Earned Value at specific date during project implementation, then calculating the schedule and budget status, and thus, schedule and cost could be controlled to achieve the project objectives.

A study conducted by (Assylkhan Ziyash) [6], indicates that EVM gets many benefits to the project managers specifically, it was determined that EVM allows recognizing schedule's delays in timely manner, predicting overruns in cost, analyzing the variances of the project's costs and schedule, as well as to forecast the outcomes of cost and time schedule. The approach also is helpful to assist project managers in their tasks to mitigate risks that related to the scope, schedule, and the cost, by informing project customers immediately about the potential issues relating the project progress, then trying to take the corrective actions.

(Khamidi M.) [7] has tested the EVM System by conducting a case study project, "Larut Tunnel", he concluded that it is possible to calculate performance of variances and indices from the case study and make it possible to check the current state, then to forecast the future cost and schedule implementation in a different ways.

The EV also is helpful to estimate and manage the risks, which may face the project, by assessing the project progress in monetary terms. It takes into account the work finished, time spent, and the cost needed to finish the project. Actually, earned value provides an important information, like the performance indices for cost - time, estimation of completion of the cost and the time, and also the measurement of the performance and the progress of the project in comparison with the budget value and actual costs relating to their matching earned values. Although the idea of applying EVM to projects under the uncertainty, is believed, in general, but the studies to confirm this are so far limited [8].

1.1. Terminology
The Application of "EVM" in the construction projects requires a systematic register for the cost and time data (once a week usually) to get the values: "ACWP" which represents the "Actual Cost of Work Performed", also "BCWP" – which represents the "Budgeted Cost of Work Performed". Another important value, named the "BCWS", represents the "Budgeted Cost of Work Scheduled" has to be realized before starting the works, which is the base of all works time schedule, and the corresponding cost plan (Fig.1) [9].

Fig. 1: Three basic curves used in the EVM

Terms relating EVM are mentioned in Table 1 [10].
BCWS | "Budgeted Cost of Works Scheduled" - the baseline of the analysis, the planned accumulative costs, which are related to the time of their occurrence
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BCWP | "Budgeted Cost of Work Performed" - measuring of the physical progressing of works, which expressed by the accumulative planned cost of the actual done works, related to time. It has another name, the "Earned Value"
ACWP | "Actual Cost of Work Performed" - accumulated amount payed for the works done, that related to time
BAC | "Budget at Completion" - the total whole project's planned cost, it is equivalent to the BCWS at planned finish.
T | The Planned period of the project

Other Important Terms relating EVM are mentioned in Table 2 [11].

| SPI | "Schedule Performance Index", which is used for estimating time completion of the project by using the performance of current date as basis. It can be determined as, "SPI = EV / PV"; if the value of SPI is one then project is within schedule, while if it smaller, then the project may describe as behind schedule, but if its value is more than one, then the project is beforehand of the schedule.
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| CPI | "Cost Performance Index" - which is used to predict the cost up to completion of project using performance of current date as basis. It can be identified by, "CPI = EV / AC"; if value of CPI is one, then the actual and planned costs are same. But if it is smaller, then the project is under the budget, and finally if its value greater than one, the project is over the budget.
| SV | "Schedule Variance (SV)" - it indicates to the comparison between the amount of work which performed in specific period to the scheduled that has to be performed. It can be calculated as:

\[ SV = EV - PV \]

A negative value for SV means that project behind the scheduled, while positive values indicates that the project in advance.

| CV | "Cost Variance (CV)" - is a comparison between the budget cost of the performed work and actual cost. Its value could be calculated as:

\[ CV = EV - AC \]

Negative value of CV indicates that project is over the budget. Positive CV indicates that progress of the project is at less than planned cost. This can be a positive sign as it indicates that project is going forward efficiently.

### 2. Methodology

The methodology undertaken for this research is summarized as follows:

- Starting with literature reviews for topics related to Earned value management, cost control, and forecasting in publications, which provided information that used to build the research framework and its base material.
- Case study for administrative building which was started at Nov. 2018, and estimated to be finished at Dec. 2019, was analyzed to be evaluated and assessed at the end of the research.
- MS project program has been used for analyzing the building, and to calculate the basic values and indices, which are used to evaluate the progress of project.
- Results obtained from the MS-project program, were analyzed and discussed to understand how the earned value method is applied and how to be utilized in assessing the projects work progress and performance.
- Finally conclusions were drawn and presented with recommendations for the future researches.
3. Application

As shown in Fig. 2 MS-project was used to analyse the planned and performance data of an administrative building. The planned schedule, which represent the baseline for the project, starts on 20th November 2018, and ends on 30th January 2020. The planned total cost, baseline cost, as shown in Figure 2, is $866,280. Planned total duration is 313 days. The status date for computing the values relating to EV was on the first of July 2019.

4. Results and Discussion

- As mentioned previously that EVM needs several terms, which have to be calculated, then indices based on that calculation should be driven. Based on those indices the project can be assessed and evaluated.
- In Figure 3 we can see that the value of BAC is equal to $866,280, which is the same planned cost for completing the project.
- The BCWS, as in Fig.3 value is equal to $298,040, which represents the baseline value of implementation for the whole project at status date.
- The ACWP value is $296,772, which represents the actual value for the work performed till status date.
- The last value shown in Figure 3 is BCWP, which represents the planned or budget cost of the work performed till status date. This value is equal to $283,560.

Fig. 3: BAC, BCWS, ACWP, and BCWP, for the project till status date
Although it is easy to compare the previous values to know or to predict the progress tendency of the project, but the indices shown in Figure 4, give a better idea about the project's progress.

- For CV value, which represents the "cost variance", it can noticed in Figure 4 that CV is equal to 13,212$, which is a positive value. It means, as indicated previously, that progress of the project is less than planned cost. This can be a positive sign as it indicates that project is going forward efficiently.

- SV value, which represents the schedule variance, is equal to 14,480$. It can be seen that SV is also a positive value, which means the project is in advance of schedule.

- CPI value, which represents the "cost performance index" is equal to 0.96. This value is smaller than 1, which means project is under the budget.

- SPI value, which represents the "schedule performance index" is equal to 0.95. This value is smaller than 1, which means the project is behind its planned schedule.

- The last value in Figure 4 is EAC, which represents the "estimate at completion", which is equal to 906,642$. It can be seen that there is a difference between this value and the baseline value, which is equal to 866,280$ as shown in figure 3.

5. Conclusions

This study shows that the earned value EVM method is actually one of the effective methods used in controlling costs. This method tracks the progress of work in different activities, as well as recording deviations from the work schedule or the planned budget of the project through the calculation of time deviation, as well as deviation of costs. It can be applied at any time of the life of the project. The benefit of calculating these deviations is the possibility of understanding the project path in order to take precautions to correct the path and control those deviations in the future.

The application of this method to one of the administrative buildings in this study, shows the existence of a deviation in cost and time schedule. These deviations are not easy to predict in the advanced stage, which was selected in this study, but it is easy to predict and calculate those deviations using this method.

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