EVALUATION THE PERFORMANCE OF THE INFRASTRUCTURE PROJECT USING EARNED VALUE MANAGEMENT

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ABSTRACT

There are many potential measures of performance for evaluating the success of a construction project. All address performance in three key areas: scope, schedule and budget. EVA addresses many project management areas including project organizing, planning, scheduling and budgeting, accounting, analyzing, reporting and change controlling. This paper explained the EVA is the best indicator of future performance by using follow-up method, and therefore, it is possible to forecast cost or schedule overruns at quite an early stage in a construction project. One infrastructure project could be used as real applications to demonstrate the advantages of EVM in extracting additional information from data about the status, trend, and future project schedule performance and associated cost.

Keywords: Earned Value, Neural Network, Infrastructure Project, Performance.

1. INTRODUCTION

Program Executive Office Air and Missile Defense (1996). Presented the earned value management process integrates the work scope of a project with the schedule and cost elements for effective project planning and control. The process supports project management by ensuring: all work scope is planned to completion and the project work scope, schedule and cost objectives are integrated into a baseline plan against which accomplishment may be measured.

EVM mainly covers the three most important knowledge areas of Project Management: Scope Management, Cost Management and Time Management. EVM unifies those three areas in a common framework that allows mathematically representing the relationship between them.
though EVM is weak in other areas of Project Management like the Stakeholders Management, it can be used to dramatically improve the success rate in projects when it is complemented with other techniques of Project Management.

2. RESEARCH JUSTIFICATIONS

The reasons that stand behind the adoption of this research work are:

1) There are different techniques currently used for measuring the performance of projects at construction stages of the project. Some of these methods suffer the major disadvantages of lack of precision, aged, slow and uncertainty.

2) Contractors used previous projects cost rates for estimation of future projects that required to be readjusted and recalculated for each project and takes into account the various site factors and conditions that influenced the earned value for construction project.

3) Construction sector in Iraq needing for modern efficient techniques to measuring and predicting the performance of projects that have more advantages such as, being modern, fast, accurate, flexible and easy to use.

3. RESEARCH HYPOTHESIS

The research hypothesis is summarized by the following statement. "The application of earned value system, as a modern technique, in Iraqi construction industry is necessary to ensure successful management, and construction companies feel with the need of such system in project management".

4. RESEARCH OBJECTIVE

The objective of this research is to demonstrate that Earned Value Management (EVM) is an effective management technique that integrates technical performance requirements, resource planning, with schedules and cost. The major objectives of applying earned value are to encourage the project managers and contractors to use effective technical, cost and schedule management control systems.

5. RESEARCH METHODOLOGY

Research methodology has adopted to involve the following:

a) Literature Survey:

Literature survey is to review the earned value system in construction sector. The concept of the earned value, benefits, structures, and applications of EV in project management field, Which include the review of literatures involving references, thesis, papers, books and web-site relating to the subject of research especially which are related to construction industry.

b) Field Work Included Four Stages:

This stage, which involved data description and identification, the data were collected from observation and recompiled to a spreadsheet format that is suitable for statistical data analysis by using computer software, such as Microsoft Project (MSP). And application of Earned Value on the Infrastructure Project as a case study.
6. APPLICATION EARNED VALUE IN CONSTRUCTION SECTOR

During the last few years or so, the use of EVM has increased in many construction engineering problems and has demonstrated some degree of success. Fleming and Koppelman (2005). Presented a general form of EVM, which makes it possible to apply for large-scale projects. Jigeesh and Bhat (2006). Concentrated on project control system and extended the EVM concept for dynamic environment based on simulation techniques. Noori et al. (2008). presented a fuzzy control chart approach considering a-cut to control earned value performance indexes including linguistics terms. In addition, a new application, based on a multi period-multi product (MPMP) production control problem was illustrated and successfully implemented. By developing an efficient forecasting method, Lipke et al. (2009) increased the project managers’ capabilities to make better managerial decisions. In order to analyze schedule performance, it also used a well-established project management method. Discussing two different perceptions of the EVM concept. Bagherpour et al. (2010), modeled the uncertainty associated with activity duration in earned value analysis. The approach incorporated a control approach, which is applicable within production control. Costs were assumed to be directly associated with fuzzy activity time estimated through a bottom up hierarchy process. Chou et al. (2010). proposed a visual architecture, design and implementation based on Web to evaluate a project performance regarding combination of EVA and database management system Pjares (2010) presented combination of EVM and project risk management to control and monitor the projects. In this work, the cost and schedule control indices were introduced. Moslemi and salehipour (2011) used fuzzy earned value indices combining with α-cut method. This work were employed to make earned value techniques more applicable under real-life and nondeterministic situations. A model was developed by (Warburton 2011) for demonstrating how to estimate final cost of the projects with faster coverage to the appropriate result and less variation than estimate-at-completion (EAC).

7. APPLICATION OF EARNED VALUE SYSTEM FOR INFRASTRUCTURE PROJECT

The Case Study of infrastructure highway Project has been taken, using the information of an actual project its cost and scheduling. The researcher will select infrastructure highway project along the 20 km in Iraq as a case study noted that the employer the Ministry of Construction and Housing / General Authority for Roads and Bridges and executing company is a White Sea General Contracting Ltd., the information of infrastructure highway project are shown in Figure (1).

![Figure 1: Information of Infrastructure Highway Project](image)

The researcher using the standard working hours in Iraq as following:

- **General**
- **Summary**
- **Statistics**
- **Contents**
- **Custom**

**Title:** Infrastructure hieway project

**Subject:** Excution of highway

**Author:** Ministry of construction and housing

**Manager:** General Authority for roads and bridges

**Company:** Wight sea company for general construction Ltd.
1) starts on Saturday and finish on Thursday
2) Working time from (8:00 - 12:00) AM and from (1:00 – 5:00) PM.
3) 8 Hour / day.
4) 48 Hour / week
5) 26 Days / month.

For infrastructure highway project as a case study which was start date is 1/Jun/2013, finishing date is 1/Mar/2014, the overall duration of the project is 14 months and the total cost equal to 20,762,500,000 I.D.

The researcher used the Microsoft Project 2013 (or MSP) is a project management software program which is designed to assist project managers in developing plans, assigning resources to tasks, tracking progress, managing budgets and analyzing workloads. The application creates critical path schedules, Cost Variance and Schedule Variance are visualized in a Report.

7.1 Cost Management Proficiency

Earned Value Analysis, also known as Earned Value Management, contains a litany of formulae that can be categorized as:

1) Earned Value Fundamental Formulae
2) Earned Value Variance Formulae
3) Earned Value Performance Formulae
4) Forecasting and To-complete performance index (TCPI)

7.1.1 Fundamental Formulae

Earned Value Management or Earned Value Analysis fundamental formulae consist of:

1) Budget at Completion (BAC): Represents the total budget cost for the project.
2) Actual Cost (AC): Represents the expenses incurred in the project till the time of measurement. Actual Cost includes all types of expenses, such as direct and indirect.
3) Planned Value (PV): Represents the planned work that should have been completed till the time of measurement. PV is calculated as: Planned Completion (%) * BAC.
4) Earned Value (EV): Represents the actual work that has been completed till the time of measurement. EV is calculated as: Actual Completion (%) * BAC.

In this Earned Value Management example, the budgeted cost of a highway project at MID 20,762,500, nearly (20,763) the project is to be completed in 14 month, note the start date is 1/Jun/2014 and the finish date is 1/Mar/2015, as shown in Figure (2) and Figure (3)
After 7.12 month, on 22/Aug./2014. The actual completed percentage has 49% of the project at a total expense (actual cost) of MID 10,177. The planned completion should have been 49% as shown in Figure (4) below:

To exploring the healthy this project is. From the Figure (5), it can be extract the following:

BAC=MID 20,763 and AC=MID 10,177
The PV and EV for all projects can then be computed as follows:

1) \( PV = \text{Planned Completion} \times BAC = 49\% \times \text{MID 20,763} = \text{MID 10,174} \) nearly 10,177
2) \( EV = \text{Actual Completion} \times BAC = 49\% \times \text{MID 20,763} = \text{MID 10,174} \) nearly 10,177

Also, the PV and EV for completed activities (earth works and layer under foundation) can then be computed as follows:

1) \( PV = \{(100\% \times \text{MID 9,000}) + (92.3\% \times \text{MID 1,275})\} = 10,177 \) nearly 10,174
2) \( EV = \{(100\% \times \text{MID 9,000}) + (92.3\% \times \text{MID 1,275})\} = 10,177 \) nearly 10,174

Interpretation: Since the PV is equal than EV, this project has delivered equal value with the planned, as shown in Figure (6) below.

Though this information is useful, it can conduct a further analysis that'll provide a clearer picture on the project costs. The fundamental Earned Value Management or Earned Value Analysis formulae set the basis analysis, such as:

### 7.1.2 Earned Value Variance Formulae

Earned Value Management Variance Formulae leverage the Earned Value Management Fundamental Formulae (BAC, AC, PV, and EV) to determine the variances pertaining to project cost and schedule. Earned Value Management Variance formulae consist of:
1) Cost Variance (CV): This is the completed work cost when compared to the planned cost. Cost Variance is computed by calculating the difference between the earned value and the actual cost, i.e. EV – AC.

2) Schedule Variance (SV): This is the completed work when compared to the planned schedule. Schedule Variance is computed by calculating the difference between the earned value and the planned value, i.e. EV – PV.

To compute the cost variance and schedule variances for highway project:

1) Cost Variance = EV – AC = MID10, 177 – MID 10,117 MID = 0.0
2) Schedule Variance = EV – PV = MID10, 177 – MID 10,117 MID = 0.0

This means that the actual cost is equal to what has been planned cost, and also, the activities of the infrastructure project have been completed within the planned durations, as shown Figure (7) which explained the earned value cost indicator's, and Figure (8) which explored the earned value schedule indicator's.

![Figure 7: Earned Value Cost Indicator's](image)

![Figure 8: Earned Value Schedule Indicator's](image)

7.1.3 Earned Value Performance Formulae

Earned Value Performance formulae consist of:

1) Cost Performance Index (CPI): Represents the amount of work being completed on a project for every unit of cost spent. CPI is computed by EV / AC.
2) Schedule Performance Index (SPI): Represents how close actual work is being completed compared to the schedule. SPI is computed by EV / PV.

From the Figure (7) and Figure (8) above, it can be computed the earned value indexes following:

1) Cost Performance Index (CPI) = EV / AC = MID 10.177 / MID 10,177 = 1.0. This means for every ID 1 spent, the project is producing only 1 ID in work.

2) Schedule Performance Index (SPI) = EV / PV = MID 10.177 / MID 10,177 = 1.0. This means for every estimated hour of work, the project team is completing 1.0 hours.

Since both Cost Performance Index (CPI index) and Schedule Performance Index (SPI index) are equal 1, therefore, the highway project on schedule and on budget.

7.1.4 Forecasting and To-Complete Performance Index (TCPI)

To gauge project performance by using Earned Value forecasting formulae, use the following:

1) Estimate at Completion (EAC): Computes project performance by looking at the total cost of the project when it is completed based on the current rate of progress.

2) Estimate to Complete (ETC): Calculates project performance by looking at the amount of money required to complete the project based on the current rate of progress.

3) Variance at Completion (VAC): Computes project performance by looking at the variance of the total project cost at completion when compared with the project budget.

4) To-Complete Performance Index (TCPI) based on BAC: Represents the level of project performance that future project work needs to be implemented to meet the budget.

5) TCPI based on EAC: Represents the level of project performance that future project work needs to be implemented to meet the project’s cost based on past project performance.

From the Figure (7) and Figure (8) above, it can be computed the earned value forecasting following:

1) Estimate at Completion (EAC) = BAC / CPI = MID 20,763 / 1.0 = MID 20,763. At the current rate, the project performance in terms coins: Project completion MID 20,763 as opposed to a planned budget of MID 20,763.

2) Estimate to Complete (ETC) = EAC – AC = MID 20,763 – MID 10.177 = MID 10,586. If the project performance continues at this rate, the project requires MID 10.586 to be completed.

3) Variance at Completion (VAC) = BAC – EAC = MID 20,763 - MID 20,763 = MID 0.0. The project will be MID 0.0 over-budgets at completion.

4) To-Complete Performance Index (TCPI) based on BAC = (BAC – EV) / (BAC – AC) = (MID 20,763 - MID 10.177) / (MID 20,763 - MID 10.177) = 1.0

5) TCPI based on EAC = (BAC – EV) / (EAC – AC) = (MID 20,763 - MID 10.177) / (MID 20,763 - MID 10.177) = 1.0
After 7.17 month, on 23/Aug./2014. The actual completed percentage has 52% of the project at a total expense (actual cost) of MID 11,000. The planned completion should have been 51%, as shown in Figure (9) below:

![Tracking Schedule after (7.17 months)](image)

**Table 1: Earned Value Analysis (7.17 months)**

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Planned Value PV (BAC)</th>
<th>Earned Value EV (BAC)</th>
<th>CV</th>
<th>SV</th>
<th>SPI</th>
<th>CV</th>
<th>C/T</th>
<th>AC</th>
<th>BAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway Project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earthworks, W</td>
<td>MID 10,000</td>
<td>MID 10,275</td>
<td>1</td>
<td>0.93</td>
<td>1.01</td>
<td>1</td>
<td>0.93</td>
<td>MID 725</td>
<td>MID 1,485</td>
</tr>
<tr>
<td>Layer under the</td>
<td>MID 9,000</td>
<td>MID 9,000</td>
<td>0</td>
<td>1</td>
<td>MID 0</td>
<td>MID 215</td>
<td>MID 213</td>
<td>1.07</td>
<td></td>
</tr>
<tr>
<td>Shoulders,</td>
<td>MID 1,275</td>
<td>MID 1,275</td>
<td>1</td>
<td>0.84</td>
<td>MID 725</td>
<td>MID 725</td>
<td>MID 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation layer</td>
<td>MID 8,000</td>
<td>MID 8,000</td>
<td>0</td>
<td>1</td>
<td>MID 0</td>
<td>MID 0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Association class</td>
<td>MID 9,000</td>
<td>MID 9,000</td>
<td>0</td>
<td>1</td>
<td>MID 0</td>
<td>MID 0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Surface layer,</td>
<td>MID 3,258</td>
<td>MID 3,258</td>
<td>0</td>
<td>1</td>
<td>MID 0</td>
<td>MID 0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

From table (1) the final results of Earned Value Analysis can be concluded: BAC=MID 20,763 and AC=MID 11,000. The PV and EV for all projects can then be computed as follows:

1) \( PV = \text{Planned Completion} (%) \times \text{BAC} = 51\% \times \text{MID 20,763} = 10,589 \text{MID} \)

2) \( EV = \text{Actual Completion} (%) \times \text{BAC} = 52\% \times \text{MID 20,763} = \text{MID 10,797} \)

Also, the PV and EV for completed activities (earth works and layer under foundation) can then be computed as follows:

1) \( PV = (100\% \times \text{MID 9,000}) + (100\% \times \text{MID 1,206}) = 10,206 \)

2) \( EV = (100\% \times \text{MID 9,000}) + (100\% \times \text{MID 1,275}) = 10,275 \)

The differences results between planning value (PV) and Earned Value (EV) for all project, comparing with completed activities, because, the calculation of Microsoft Project depended on works hours.

The Figure (10), shows the variance over time, cost and schedule variance for the infrastructure highway project on status date after 7.17 months from start date, the value of cost variance (CV) is negative about (-MID 725), then, the highway project is over budget. But, the value of schedule variance (SV) equal to (+ MID 69). This value (SV) is positive, then, this project is ahead of schedule. Cost Variance and Schedule Variance can be computed as:
1) Cost Variance (CV) = EV – AC = 10,275 MID -11,000 MID = -725 MID
2) Schedule Variance (SV) = EV – PV = 10,275 MID -10,206 MID = 69 MID

This means that the actual cost is greater than to planned cost, and also, the activities of the highway project have been completed with little time.

![Figure 10: Variance Over Time After (7.17 months)](image1)

From figure (11) can be shown the performance index where:

1) Cost Performance Index (CPI) = EV/AC = MID 10,275 / MID 11,000 = 0.93
2) Schedule Performance Index (SPI) = EV/PV = 10,275 MID /10,206MID = 1.01

Since the Cost Performance Index (CPI) is equal 0.93 and Schedule Performance Index (SPI) is over equal 1, therefore, the highway project ahead of schedule and over budget.

![Figure 11: Indicate Over Time after (7.17 months)](image2)

Also, the researcher calculated the forecasting index , Estimate At Completion (EAC), Estimate To Complete (ETC), Variance At Completion (VAC) and To-Complete Performance Index (TCPI), where:

1) Estimate at Completion (EAC) = BAC/CPI = MID 20,763/0.93=MID 22,325 nearly 22,228.
2) Estimate to Complete (ETC) = EAC–AC=MID 22,325-MID 11,000=MID 11,325. If the project performance continues at this rate, the project requires MID 11,325. to be completed.
3) Variance at Completion (VAC) = BAC – EAC = MID 20,763 - MID 22,325 = - MID 1.562 nearly -1.465 MID. The project will be MID 1.465 under-budget at completion.

4) To-Complete Performance Index (TCPI) based on BAC = (BAC – EV) / (BAC – AC) = (MID 20,763 - MID 10,275) / (MID 20,763 - MID 11,000) = 1.07.

5) TCPI based on EAC = (BAC – EV) / (EAC – AC) = (MID 20,763 - MID 10,275) / (MID 22,325 - MID 11,000) = 0.926.

8. CONCLUSION

1) The researcher found that the Microsoft Project 2013 is the active and useful program in follow-up the projects performance especially in Infrastructure Project by using Earned Value Management; it is a way to help the projects managers in control the progress of work.

2) EVA is the best indicator of future performance and therefore by using trend data it is possible to forecast cost or schedule overruns at quite an early stage in a construction project.

REFERENCES