

Application of Earned Value Management in Project Management

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Abstract: Today, firms may cut costs through improved information exchange and boost profitability by delivering goods more quickly and affordably with fewer resources thanks to the scientific use of project management. In these projects, the core management activities revolve around cost management. This requires project managers to follow a scientific approach to strict project budgets, identify deviations early, analyse problems and correct them in a timely manner. Therefore, this paper aims to introduce the meaning and methods of cost management and introduces the basic concept of earned value management after analysing the history and current status of cost management to optimize its theory. By analysing the interplay between project cost and schedule, this paper explains how to apply earned value management to project cost control process by using cost and schedule performance index analysis and so on. The paper concludes with an analysis of the limitations and some countermeasures and suggestions. Cost management of projects should take into account the variability of the project and take into account both time and quality factors.

Keywords: project management, cost management, earned value management

1. Introduction

1.1. Background

According to the definition given by the American Project Management Institute, A project is a brief endeavor designed to produce a specific good or service [1]. It has a certain uniqueness compared to business management, which is aimed at businesses and the variety of controlled and repetitive production and operational activities in them. Project management is one-time and unique, which means that each project has its own defined starting point and end point, which necessarily includes something that has never been done before. Any project is divided into four phases: initiation, planning, execution, control and closure. Projects have multiple objectives such as cost, quality, and schedule [2]. Project management is widely adopted as a modern management approach and methodology to control project scope, cost schedule and quality, and to ensure successful implementation of the project. However, in practice the uncertainty of the project's environmental conditions leads to certain risks in the project execution process, to only want stagnation, delays, cost overruns or substandard quality or even cases of major accidents leading to project termination or failure [3]. Project cost management is a series of activities such as cost estimation, cost budgeting, and cost control in order to control the actual cost of the project within the project budget [4]. It is

used throughout the project process and in all aspects. By managing the cost of a project, it can be completed efficiently within the budget, thus minimizing the project cost and maximizing the project value (economic return). Therefore, project cost management plays a crucial role in whether a company can occupy a favourable position in the fierce market competition and gain higher profits.

1.2. Literature Review

The "Project Management Body of Knowledge Guide (PMBOK Guide)" prepared by the Project Management Institute states that the total expenses incurred across a project's full life cycle make up project cost management [1]. The Project Evaluation and Review Technique (PERT/Time), the first of a number of integrated management techniques for project duration and cost, was developed, which was introduced in 1958 by the U.S. Department of Defense to study the U.S. Navy. This was followed by PERT (Program Evaluation and Review Technique)/Cost, an integrated management method for project cost and schedule, which was not successful [5]. Later, in order to create the "Cost/Schedule Control Systems Criteria-C/SCSC," the US Department of Defense created the US Air Force in 1967. [6], which was the prototype of earned value management and is now improved several times to become Eun Hong Kim introduced the four factors of EVM (Earned Value Management) users, EVM implementation was built using the usual EVM methodology, implementation procedure, and project environment. The model can successfully address the issue of project cost control. They made the point that implementing the EVM model in various organisations and projects can offer precise analysis of cost and schedule variances that arise during project implementation. [7]. Narbaev and Marco established a growth model combining nonlinear regression cost estimation and earned value in order to increase the precision with which building projects' final costs are predicted, and considered duration as a decisive factor for cost control [8]. Colin et al. came to the conclusion that the standard earned value management model cannot adequately consider the EVM/ES systems' multidimensional nature, and as a result they presented a multivariate model for EVM/ES systems that permits principal component analysis in system scheduling [9].

1.3. Framework

In summary, project management and cost management have received a lot of attention from scholars at home and abroad, and it is important to sort out and analyse the current status of research applications in this field, and then summarize potential future research directions. Based on the current status of project cost management, this paper investigates the earned value analysis method, cost and schedule deviation analysis table and other tools to analyse and forecast the schedule and cost of the project in real time, and provide cost control information for the project progress, taking into account the development process and characteristics of the project as well as the current cost management system.

The structure of this paper, which is broken up into five chapters, is as follows. Chapter 1 is introduction, which introduces the development and status of project management and cost management as well as the main content and structure of the paper. The overview and methodology of project cost management are covered in Chapter 2, which also presents the concept of project cost management, its significance, the project cost management process, and the cost components. Chapter 3 introduces how earned value management is applied in the cost control process, analyses the coordination of project cost control and schedule control and summarizes the specific methods. Chapter 4 provides some limitations of the current status of project cost management and possible future research directions. Chapter 5 is the conclusion, which mainly summarizes the research content of the whole text.

2. Methodology

To gain a clearer understanding of cost management, this chapter first introduces the definition and components of cost management. After that, it demonstrates the value of cost management in project management and shows how to do it efficiently.

2.1. Cost Management Definition

Cost management in project management is the sum of costs over the full life of the project. It ensures that projects are completed within budget by estimating, budgeting, and controlling cost for the project [1]. Cost estimation is the estimation of the amount of money required to complete a project. Cost estimation requires the use of appropriate tools for different project products. Common cost estimating tools include bottom-up, top-down, similar-to, Program Evaluation and Review Technique (PERT), and parametric estimates [10]. Cost control is the act of keeping track of the project's status and updating the project cost and change baseline as the project moves forwards. Budgeting is the process of combining the costs of all jobs and generating an acceptable baseline.

2.2. Budget Development

The budget contains a resource budget and a cost budget. The resource budget is mainly related to human resources. It requires an estimate of the labour and time commitment of the project. Resource budgeting involves assessing the workload based on the project requirements and assigning it to each phase of the project based on the Work Breakdown Structure (WBS). The cost budget is an estimate of the cost of the project, such as the purchase of equipment. In addition, the project budget should take into account the management reserve, a contingency reserve that is used to address unexpected situations in the project. The components of a project budget are shown in the Fig. 1 [1].

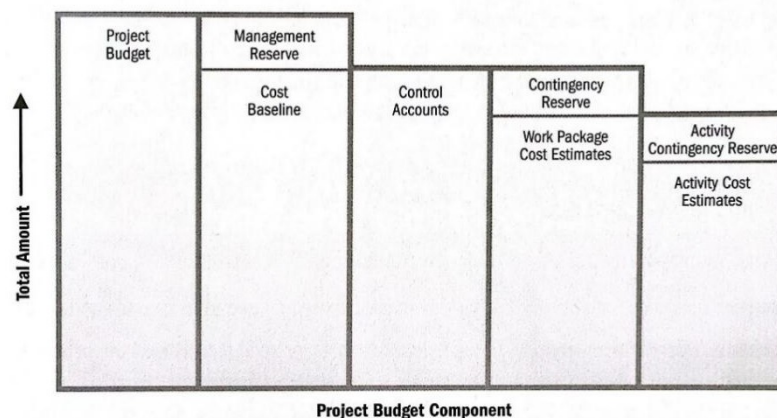


Figure 1: Project Budget Component [1].

2.3. Effective Cost Control

The budget should serve as a guide for the project manager as they continue to manage the project in order to limit expenses and increase income. During the project process, the project manager should track the project's actual costs, compare them to the budget, and do data analysis so that the project manager can make real-time statistics and adjust the decision in time.

2.4. The Significance of Cost Control

Prior to the project's launch, a solid financial plan is essential, as is real-time data input while the project is in progress. To improve project cost management and make it more rational and scientific, these two types of data are analyzed and managed by project managers. The project cost management can help project managers understand project trends and comparative status and analyse project status to support project managers' decision making. Only by using and analysing the budget and actual data of the project can cost control be achieved to ensure the healthy development of the project. A successful project is one that achieves the expected performance within certain cost and time constraints. Cost management is of absolute importance relative to project performance, and lots of projects have been terminated because of rising costs [11]. A cost-benefit analysis of a project can effectively determine the feasibility of the project.

3. Earned Value Management

Cost management benefits from the project management methodology known as Earned Value Management (EVM). As a project management tool that focuses on cost and schedule, it ensures that the project progresses as expected and ultimately achieves the desired benefits. This section provides a definition of earned value management, the key indicators and how to analyse the project based on the calculation results.

3.1. Definition of EVM

Earned value management is a method for gauging and depicting the actual progress made on a project. The approach combines the three crucial elements of project scope, time, and cost. Evaluation and control of the project is achieved by monitoring the completion of tasks, the time to completion, and the costs incurred [12]. An important use of the Earned Value Analysis method is to make a forecast of the total cost estimate (EAC-Estimate at Completion) for future projects at completion. This forecast's goals are to give data for controlling the project's fertility work costs and to serve as a foundation for project financing in the future. Table 1 displays the four fundamental values used in the Earned Value Method.

Table 1: Basic values in EVM.

Name	Description
Planned Value (PV)	Estimated expenses intended to be spent on a project at a specific timeframe.
Actual Cost (AC)	The total cost incurred to finish the task in a specific time frame, including direct and indirect expenditures.
Earned Value (EV)	The value of the task that was completed.
Budget At Completion (BAC)	The budget planned to complete the whole project.

3.2. Analysis Based on EVM

3.2.1. Performance Indicators

The performance of projects needs to be analysed in various projects. This includes the cost performance of the project and the schedule performance of the project. In the analysis of PV, AC and EV, the formulas used to analyse are shown in Table 2.

Table 2: Cost and schedule performance analysis.

Name	Formula	Definition
Cost Variance (CV)	$CV=EV-AC$	The difference between the projected value and the actual costs spent up to a specific time. When $CV>0$, the actual project cost is under the planned project cost, i.e., the project is progressing well, and vice versa.
Schedule Variance (SV)	$SV=EV-PV$	The difference between current progress and planned progress up to a certain point in time. Project progress is made ahead of schedule when $SV>0$, and vice versa.
Cost Performance Index (CPI)	$CPI=EV/AC$	The actual value earned back per unit of cost according to the scheduled project schedule. When the $CPI >1$, the actual project cost is under the planned project cost, i.e., the project is progressing well, and vice versa.
Schedule Performance Index (SPI)	$SPI=EV/PV$	It is a measure of progress performance. When SPI is more than 1, the project is moving ahead of schedule, and vice versa.

Considering cost deviation or schedule deviation alone does not properly analyse the actual status of the project. When the CV is negative, it is a direct response that the actual cost spent exceeds the planned cost. However, there are two cases in this state, one is that the project is progressing more than expected and the actual work done exceeds the work planned to be done, in this case the negative CV cannot represent the bad progress of the project. The other case is that the project is not progressing as expected and the costs are overspent. In this case, the project manager needs to find the problems in the project and make timely adjustments. Three possible conditions in the project process are shown in the following figures. For Fig. 2, the project is moving ahead of schedule and it can be forecast that the project will be completed on schedule and under budget, and the project manager can allocate resources appropriately. For Fig. 3, The project manager can reasonably arrange the duration according to the current situation of the project. For Fig. 4, If necessary, the project manager should eliminate unnecessary project activities and reschedule subsequent projects to ensure the project budget.

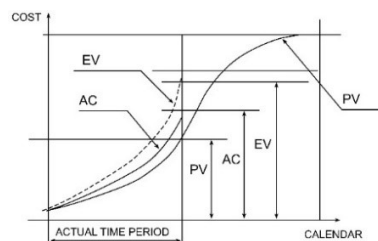


Figure 2: Under budget & ahead of schedule. (Photo Credit: Original)

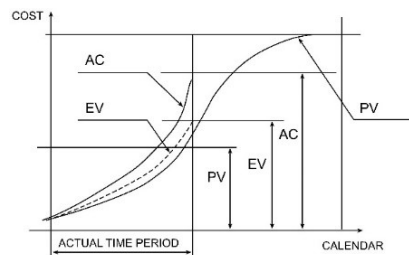


Figure 3: Over budget & ahead of schedule. (Photo Credit: Original)

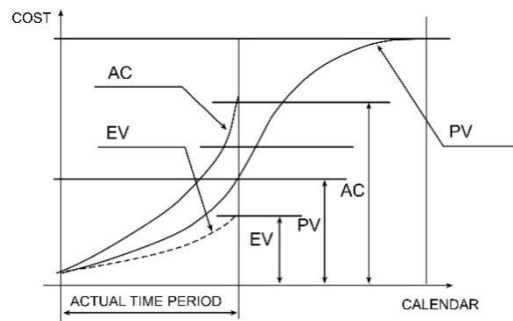


Figure 4: Over budget & behind of schedule. (Photo Credit: Original)

3.2.2. Forecasting Indicators

The future state of a project is estimated and projected using forecasting methodologies based on the information that is now accessible, and the forecast results are created and updated depending on the work performance data that is available as Shannon executes and develops. Performance data is knowledge about how a project has performed in the past and how it could perform in the future. Table 3 displays the budget parameters and formulae.

Table 3: Forecasting Indicators.

Name	Definition	Formula
Estimate To Completion (ETC)	How much the remaining work will cost in addition.	(1) At the present CPI, if the remaining work is still completed: $ETC = (BAC - EV) / CPI$ (2) Complete the remaining work at planned CPI (CPI=1): $ETC = BAC - EV$ (3) If the project is strictly required to be completed by the planned time (with additional costs to meet the schedule): $ETC = (BAC - EV) / (CPI * SPI)$
Estimate At Completion (EAC)	Estimate the project's overall cost at a specific point in time.	The actual cost already spent plus ETC: $EAC = AC + ETC$ At the present CPI, if the remaining work is still completed: $EAC = BAC / CPI$
Variance At Completion (VAC)	The total project cost deviation at the time of completion is known at a certain point in time.	$VAC = BAC - EAC$

Based on the different project completion cost forecasting methods shown in Table 3, the diagram can be seen in Fig. 5.

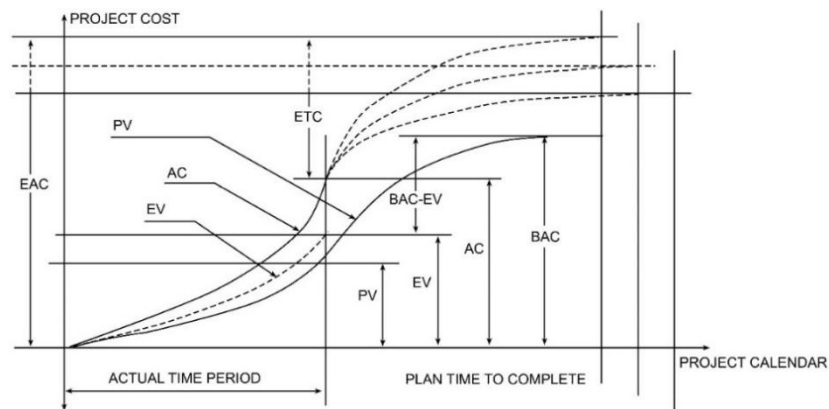


Figure 5: Forecasting with different formulars. (Photo Credit: Original)

In fact, most project cost and schedule plans can be adjusted, forecast, and scheduled according to certain correlations [13]. Few projects can be planned well from the beginning and not require changes and adjustments at a later stage. In this forecasting method, the project duration and cost should be integrated to achieve the rational allocation and integration of project cost and duration [14]. In some specific cases, To make sure the project can be finished on time, the project manager must employ additional costs and assure the project's length. Another scenario is where the project budget is highly constrained. In this case, the project manager must use the defined project budget as the basis for integrating the management of project cost and schedule through the sensible scheduling of project activities and duration. When the actual project cost is higher than the planned project cost and it can be inferred that the project completion cost will exceed the project budget, it is necessary to re-forecast and re-arrange the subsequent project duration and activities by reducing the project activities to ensure the total cost is under budget.

4. Limitations and Future Work

4.1. Limitations

The current earned value management approach in cost management suffers from poor adaptiveness, lack of weight discrimination and application limitations. Earned value management is based on cost targets and planned value. However, in the actual management process, the cost target of the project is always in a state of flux. In order to obtain effective calculation results, The project cost baseline must be updated often to reflect the project's current position. In addition, earned value management ignores the fact that different tasks have different importance in the execution process, which leads to deviations in the results. In addition, the actual data collection process can produce data discrepancies and cannot guarantee the accuracy of the data, so it does not reflect the real situation of project execution and cannot solve many problems of quality, safety, etc. This paper only analyses cost and schedule among the three elements of project management, but the interrelationship of the three elements can be considered in future papers to introduce more variables for analysis and argumentation. Therefore, the earned value approach to pure cost and schedule management can easily create risks to quality, safety important projects. Inaccurate or human factors might also cause project execution results to differ from the intended outcomes. A flawless monitoring strategy does not ensure effective project management. In order to control the project and make flexible analyses and forecasts in light of the real situation during execution, managers must make effective use of information.

4.2. Future Work

With the increasing complexity of projects and the development of big data analysis technology, earned value project management can be based on the multiplicity, dynamism and adaptiveness of big data analysis technology to identify project cost and schedule deviations by collecting historical project task data. Combining Big Data and project management to identify project deviations and control project risks improves the traditional earned value management method. The dynamic nature of Big Data allows the project team to continuously accumulate project-related data and information from project inception, extracting project task attributes such as duration, workload, and deviations to build analytical models to support project cost management. The results of this data can be used in ongoing projects to predict the potential deviations more accurately at completion. The real-time processing of this data extends the range of resources and conditions available to the project, allowing for more scientific decision-making in project management and providing the potential for continuous improvement and enhancement of project management.

5. Conclusion

Overall, this paper presents project cost management, examines it, and describes how earned value management is used to project cost management. It shows that cost management is an important criterion for the success of a project, together with time management and quality management, throughout the project management process. The quality of the project also has an impact on the cost. Therefore, the two-dimensional space can be expanded into a three-dimensional space according to the influencing factors when conducting earned value analysis. The use of earned value analysis of project cost and schedule analysis, you can clearly see the project in each stage of control and adjustment of the focus and timely control and adjustment of control measures, the final cost of the project also has a forecast and not in the final stage of the project appears serious cost overruns, progress behind schedule situation and lead to project failure. Cost control and forecasting is not accurate enough to rely on the cost performance index alone and needs to be analysed in conjunction with the current project schedule to determine whether the cost balance is due to schedule lag or cost overrun due to schedule advance. The integrated management of work quality and work quantity is concerned with the integrated management of project cost and schedule in the project earned value management system. which can be fully extended to various management areas of the management control dual elements.

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