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A modified earned value management using activity based costing

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A B S T R A C T

Earned Value Management (EVM) has been a well-known methodology used since the 1960s when the US department of defense proposed a standard method to measure project performance. This system relies on a set of often straightforward metrics to measure and evaluate the general health of a project. These metrics serve as early warning signals to timely detect project problems, or to exploit project opportunities. A key aspect of EVM is to estimate the completion cost of a project by considering both cost and schedule performance indices. However, good performance of cost and schedule performance indices does not necessarily guarantee cost effectiveness of the project regardless of the overhead costs. The reason is because, in most project-based organizations, overhead costs constitute a significant proportion of the total costs. However, EVM indices are usually calculated in the absence of the so-called overhead costs. This paper, first, seeks to remedy this problem by proposing a practical procedure of allocating overhead costs in project-based organizations. Then the traditional EVM indices are revised by considering the allocated overhead costs. Finally, a case study demonstrates the applicability of the proposed method for a real-life project.

1. Introduction

Cost monitoring and control are important activities that affect project management success. Difficulties arise, however, when an attempt is made to implement these activities that is why, integrating cost information with scheduling and technical details of a project in a comprehensive and logical framework has always been a challenge for project managers. In this regard, earned value management is a well-known method established in order to cover all these needs and expectations. However, EVM does not take into account the impact of overhead costs in its calculations while overhead costs constitute a significant proportion of the total costs of a project (portfolio). The idea behind this paper is to develop a practical approach for allocating the overhead costs in EVM calculations. With the help of the proposed approach, the traditional cost and schedule performance indices are revised by which a

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project manager (or project cost and schedule analyst) can have a better view of what actually has happened in the project.

In the following of this paper section 1.1 provides a brief overview of the recent history of EVM technique. Section 2 begins by laying out the theoretical dimensions of cost allocation systems, and it will go on to time-driven activity-based costing. Section 3 and 4 describe the design, procedure, and implementation of the proposed method. The last section shows the applicability of the method in a real-life portfolio.

1.1. Earned Value Management

According to the Project Management Body of Knowledge (PMBOK) 5 edition, Earned Value Management is a methodology used to measure the real physical progress of a project and to integrate, at least, three critical knowledge areas of project management including scope, time and cost management (PMI, 2013). It considers the work completed, the time taken and the expenses occurred to complete the project, and it also helps to evaluate and control project risks by measuring project progress in monetary terms. EVM's three basic components are actual cost (AC), planned value (PV) and earned value (EV) (Vanhoucke, 2009). The Planned Value, PV, includes the time-phased budget baseline as an immediate description of the schedule built from the project network. It is an increasing trend in the total budgeted cost of work scheduled. The summation of planned values at the end of the project is considered as "Budget at Completion" (BAC). The Actual Cost (AC), is associated with the actual cost of work performed and is the cumulative actual cost devoted to a given point in time. In addition, the Earned Value (EV) is the amount of the budgeted cost for executing the work accomplished at a given point in time. It is normally called budgeted cost of work performed and is measured by multiplying the project budget at completion and percentage of the project progress at a specific point in time. The key parameters mentioned above can be implemented to measure the current and past performance of the project in progress also they can be implemented as early warning signals to determine project problems and opportunities (Vanhoucke, 2012).

The literature on the EVM and its related topics is rich and widespread. Generally, we can categorize these topics into two groups. The first group tries to develop EVM concepts and models, while the second group attempts to find out the applications of the EVM, not only in different projects but also in different organizations. In the first group, some of the remarkable works are as follows. Managing cost and schedule in projects using performance indices developed by Lipke (1999) and he provided earned schedule (ES) concept to overcome the quirky behavior of the Schedule Performance Index, SPI (Lipke, 2003, 2009). He also proposed an improved schedule performance measure that is directly expressed in time units. ES is an extended version of the EV and PV metrics which relies on similar principles of the earned value. A year later, two studies were performed (Henderson, 2003; Henderson, 2004) on the reliability of ES. In 2006, Vandevoorde and Vanhoucke (2006) analyzed the reliability of the ES related formulas compared with the traditional formulas. Cioffi (2006) presented standard EV parameters, which made EV mathematics more flexible and applicable. Moslemi Naeni and Salehipour (2011) used fuzzy logic and applied the degree of possibility method to improve the estimations in our real life projects. Bagherpour et al. (2010) designed a control mechanism using earned value analysis and showed its application to the production environment. Warburtun (2011) developed a formal method to include time dependencies to the EVM system. Mortaji et al. (2013) incorporated L-R fuzzy numbers in EVM indices in order to deal with the inherent uncertainty of project tasks. A detailed explanation of EVM basis can be found in (Anbari, 2003; Fleming & Koppelman, 2010; PMI, 2013).

The second group also includes many important researches. For instance, Anbari (2003) discussed the implementing of the EVM in practice. Later, EunHong et al. (2003) developed a model which was resulted from two years of study in different organizations and projects. Specifically, Wi et al. (2009) analyzed how project performance can be measured in virtual organizations. Vitner et al. (2006) used data envelopment analysis (DEA) in order to evaluate the performance of multi-project environments.

Benjaoran et al. (2007) developed former cost control system for the small and medium contractor in ICT industry and adopted it to the earned value concept. Lipke et al. (2009) predicted the project income by using a different statistical forecasting model. This prediction can enable project managers to make more accurate decisions. Naderpour and Mofid (2011) used earned value management to improve construction management. They compared traditional project management methods with the earned value management system for a construction project in an educational center. Aliverdi et al. (2013) implemented this method in a construction project and monitored changes in cost and schedule indicators using an I-MR control chart.

As is clear from the above-mentioned works although extensive studies were carried out on the EVM, no single study exists which adequately covers the association between overhead costs in a project and its effects on the EVM indices. That is why this paper seeks to develop a new approach for allocating overhead costs in EVM parameters. The Next section begins by laying out the theoretical dimensions of cost allocation systems from traditional methods to activity-based costing method, and it will go on to time-driven activity-based costing.

2. Theoretical background

2.1. From traditional cost allocation systems to activity-based costing

Finding the profitability of each customer, product, or activity was traditionally done by allocating costs to customers according to the sold items (Cooper, 1988). However, due to the limited amount of cost data, it was reasonable to use volume-based cost related data allocation models (Cooper & Kaplan, 1988). In reality, it is evident that some operations such as the fact the sale order processing do not vary per unit sold, rather they are dependent on the number of sales orders for each customer. Customers who make frequent purchases in small packages generate more overhead costs than those who make fewer frequent purchases in bigger packages. Hence, by increasing the complexity of the business environment, traditional cost allocation systems became less beneficial in providing accurate cost information (Cooper, 1987; Drury, 1990).

Due to the drawbacks of the traditional cost allocation systems, Activity Based Costing (ABC) was developed in 1980 in order to reply to inaccurate American accounting systems (Kuchta & Troska, 2007; Mortaji et al., 2013). ABC enables organizations to calculate more accurate information about their cost consuming activities. That is why the ABC clarifies that different customers may have various amounts of activities and resources. So, it is concerned with what is performed in terms of activities instead of what is spent. One of the main difference between this method and other methods is a set of cost drivers that are collected in a pool called activity cost pool (Charles & Hansen, 2008). It can be said that ABC models the causal relationships between products and the resources used in their production, and traces the cost of products according to the activities through the use of appropriate cost drivers (Bogdănoiu, 2009).

Although ABC was acceptable and more effective than the former cost accounting systems, it was faced with some difficulties during its implementation. These difficulties were mostly related to its performance and implementation complexity. And they were severe enough to make Kaplan, as one of the originators of ABC, state that it is better to abandon this approach (Kaplan & Anderson, 2007). The most common reasons reported for the problematic implementation of ABC are: i. data collection in this approach is time-consuming and requires a high degree of staff cooperation and commitment ii. there are too many cost drivers and activities that need to be identified and iii. it is usually very hard to recognize the unused capacities of resources in practice (Ratnatunga & Waldmann, 2010). Furthermore, model updating is another problem that many organizations faced with and it usually causes repeating the interviews. For example, when a new activity is added or removed (Kaplan & Anderson, 2007; Pernot et al., 2007). The obstacles mentioned above led to the development of a new method called Time-Driven Activity-Based Costing (TDABC).

2.2. Time-Driven Activity-Based Costing

Because the ABC was time-consuming and costly, Kaplan and Anderson developed improvements in the process through what they call time-driven ABC. Time-driven ABC decreases the amount of data needed, and only requires estimates of two things: i. the practical capacity of committed resources and their cost, and ii. unit times for performing transactional activities. The aim of the TDABC is to overcome the administrative problems of the ABC approach and to simplify the complexity of gathering and updating data. TDABC identifies the capacity of each department or process and then allocates the cost of this capacity of resource groups over the cost object based on the time required to perform an activity. If the demand for work in these departments or processes declines, TDABC can estimate the quantity of resources released (Kaplan & Anderson, 2007). The main difference between ABC and TDABC is in their calculation procedure. In ABC, staffs are asked about how much time they consume for different activities; and based on this information, costs are assigned to the activities. However, TDABC focuses on the spent resources. Table 1 shows the difference between ABC and TDABC.

Table 1
Activity-based costing versus time-driven activity based costing. Source: (Kaplan & Anderson, 2007)

ABC step by step procedure	
Step 1	Identify the different overhead activities
Step 2	Assign the overhead costs to the different activities using a resource driver
Step 3	Identify the resource driver for each activity
Step 4	Determine the resource driver rate by dividing the total activity costs by the practical volume of the activity driver
Step 5	Multiply the resource driver rate by the resource driver consumption to trace costs to orders, products or customers
TDABC step by step procedure	
Step 1	Identifying resource groups and the activities for which they are used
Step 2	Defining the costs of each group
Step 3	Estimating the practical capacity of each group (e.g. available working hours, excluding vacation, meeting and training hours)
Step 4	Calculating cost per time unit by dividing the total cost of the resource group by the practical capacity
Step 5	Determining the required time units for each activity
Step 6	Calculating cost per transaction by multiplying the unit cost of each resource group by the time estimate for the events

3. Problem statement

As illustrated in Fig. 1, price breakdown structure for a project-based company may include (but not limited to) three main parts.

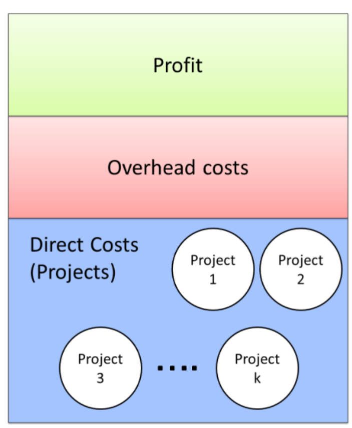

Fig. 1. Price breakdown structure of a project-based company

The first part is the direct costs which are directly spend on projects. The second part constitutes the overall profit and legal deductions (such as tax and insurance). This type of costs is calculated by the expected profit for each project. And the third part is the company's overhead costs, which are not easily assigned to projects. Overhead costs may be spent in different ways such as: general staff, the board of directors, training, advertising, attending seminars and conferences, and other general costs; and that is why they are not clearly distributed to a specific project or activity. Although these costs are indirectly spent on projects, but they usually are not considered in contracts while those can impose high expenditure and reduce the corporate's profitability index.

The purpose of this paper is to answer the following questions:

I. How to assign corporate overhead costs to projects undertaken;
II. How EVM metrics should be revised in presence of overhead costs.

The rest of this paper is organized as follows: Section 4 discusses how to allocate company overhead costs to projects. Then, in section 5, traditional EVM indices will be developed considering the company's overhead costs. Section 6 brings an illustrative case to prove successful implementation of the proposed method in real case applications. Finally, in section 7, the paper ends with conclusion and notes on future research directions.

4. Allocating company's overhead costs to projects

Overhead costs cannot be easily allocated to specific activities, departments or projects. If the method does not allocate the true amount of overhead costs (for example in a manufacturing system), cost per unit will be estimated wrongly, and may causes a flawed decision making by management. Equal division of company's overhead cost among all activities, departments, or projects is the most common way to allocate overhead costs. In this case, the profitability of each project will be vague for managers and they wouldn't know how much profit has been obtained on each project. Hence, in this paper, overhead cost allocation has been done using the ABC technique, which is simple, powerful and also easy to use. For this purpose, the authors listed three approaches (cost driver) as follows.

1- Profitability of each project;
2- Budget at completion (BAC) of each project;
3- The amount of equipment and staff incurred for each project.

First of all, it is worth mentioning that using the profitability of each project to allocate more overhead costs to projects that made more profit for the company, may not be a wise decision. More benefits of a typical project can be the result of a series of factors such as: good management, better payment and etc. Allocating more overhead costs to these kinds of projects would not be logical. It could also mislead project managers to make a project less profitable in order to avoid the high overhead costs.

On the other hand, having greater estimated BAC wouldn't be a good reason for allocation of more overhead cost. Since complexity may increase during the project implementation, a project might need staffs with more proficiency and/or more advanced equipment. Besides, BAC can have a positive correlation with project complexity. So, for projects with more complexity, more amount of budget is needed.

However, the third cost driver is more logical than the former ones. The number of staffs and equipment that are being used in a project are the main sources of overhead costs. There is no doubt that the project with more general staff and equipment to be applied generates more overhead costs.

According to the mentioned reasons, authors suggest that the company's overhead costs should be allocated to projects based on the number of staffs and equipment incurred in general resource pools. To build up a generalized mathematical model for project-based organizations, the following notations are presented as given in Table 2.

Table 2
Notations and abbreviations

Defined quantity	Standard Notation	New notation (revised formalism)	Equation no.
Project *k* man-hour.	------	$P_{mh(k)}$	1
company man-hour	------	O_{mh}	2
Project *k* weight.	------	$W_{p(k)}$	3
Working time of staff *i* in project *k*.	------	T_{ik}	------
Working time of equipment *j* in project *k*.	------	T_{jk}	------
Equipment *j* conversion factor to convert equipment-hour	------	α_{jk}	------
Company's overhead cost	------	OH_O	------
Internal overhead cost for a project that generated with the	------	$OH_{P(k)}$	------
Proportion of company's overhead cost assigned to project	------	$OH_{o/p\ (k)}$	4
allocated overhead cost to project k	------	$\Delta_{(k)}$	5
Proportion of control plan *l* in planned progress. *L* is the	$PP_{(l)}$	$PP_{(l)}$	------
Planned progress	*PP*	*PP*	------
Actual progress	*AP*	*AP*	------
Net budget at completion of project	------	*NBAC*	------
Actual cost of work performed (ACWP) or Actual cost	*AC*	$AC_{(r)}$	7
Budget cost of work scheduled (BCWS) or Planned value	*PV*	$PV_{(r)}$	9
Budget cost of work performed (BCWP) or Earned value	*EV*	$EV_{(r)}$	10
Cost performance index	*CPI*	$CPI_{(r)}$	11
Schedule performance index	*SPI*	$SPI_{(r)}$	13
Cost variance	*CV*	$CV_{(r)}$	14
Schedule variance	*SV*	$SV_{(r)}$	15
Estimate at completion	*EAC*	$EAC_{(r)}$	16
Estimate to complete	*ETC*	$ETC_{(r)}$	17
To complete performance index (based on BAC)	$TCPI_{BAC}$	$TCPI_{BAC(r)}$	18
To complete performance index (based on EAC)	$TCPI_{EAC}$	$TCPI_{EAC(r)}$	19

The revised variables are displayed with the index "r", standing for 'revised'. Also, Variable boundaries are stated as follows:

$(1 \le i \le n)$; $(1 \le j \le m)$; $(1 \le k \le K)$; $(1 \le l \le L)$; $(\alpha \ge 0)$

Allocation of each project overhead, needs the total man-hour spent (or are going to be spent) on each project. Besides, projects use different types of equipment too. Hence, α_j has been defined in order to convert machine-hour of equipment type j into man-hour. This parameter is strongly related to the type of equipment. Eq. (1) is used in order to achieve project k man-hour.

$$P_{mh(k)} = \sum_{i=1}^{n} T_{ik} + \sum_{j=1}^{m} \alpha_{jk} T_{jk} \quad (1)$$

The summation of $P_{mh\ (k)}$ is the company's man-hour. So Eq. (2) is as follow:

$$O_{mh} = \sum_{k=1}^{k} p_{mh(k)} \quad (2)$$

According to 1 and 2, the weight of project k would be calculated using Eq. (3):

$$W_{p(k)} = \frac{P_{mh(k)}}{O_{mh}} = \frac{\sum_{k=1}^{k} T_{i(k)} + \sum_{j=1}^{m} \alpha_j * T_{j(k)}}{\sum_{k=1}^{k} p_{mh(k)}} \quad (3)$$

By assigning the weight of each project (Eq. 3) and the company's overhead cost, the allocation of each project will be achieved simply by multiplying the weight of each project by company's overhead cost which is shown in equation No.4:

$$OH_{o/p(k)} = W_{p(k)} * OH_o \tag{4}$$

On the other hand, project k generates some internal overhead cost that is created by its own efforts. This type of overhead is shown in this paper as $OH_{P(k)}$. Generally, a typical project k will have the following amount of overhead calculated using Eq. (5), which is the summation of the project and the company's overhead.

$$\Delta_{(k)} = OH_{o/p(k)} + OH_{p(k)} \tag{5}$$

With considering Eq. (5), the total overhead cost for a project can be obtained more accurately. The step by step instruction to derive total overhead costs related to a project has been illustrated in Fig. 2.

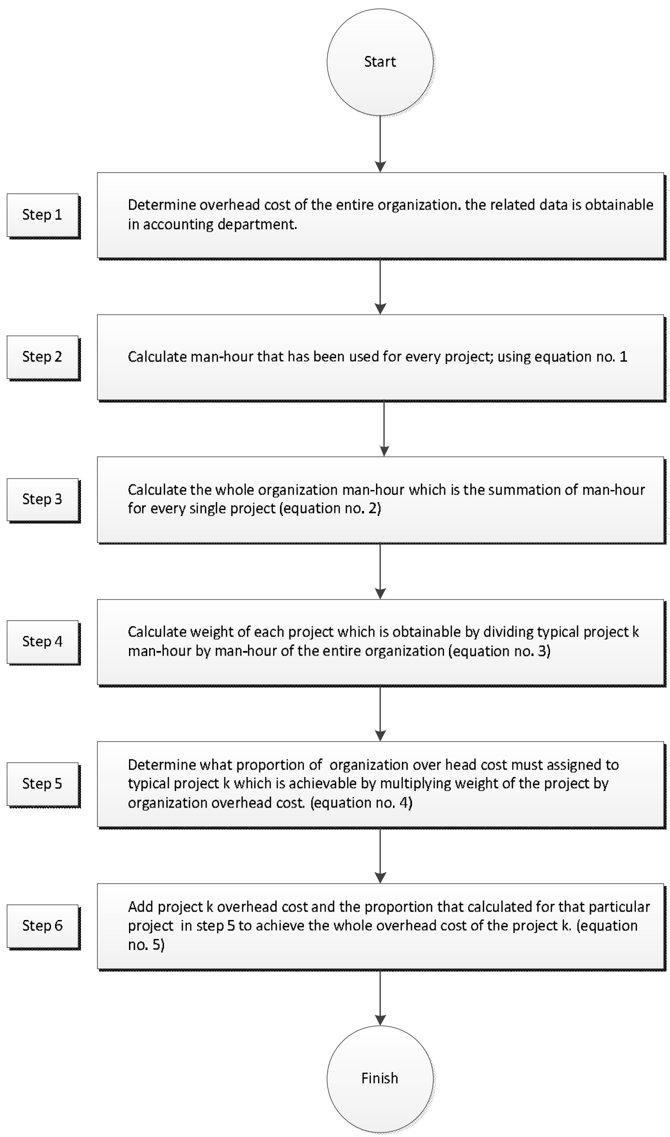

Fig. 2. Step by step instruction of company's overhead allocation

5. A revision in EVM indices

Since the early years of its implementation, EVM has been a useful tool for managers to estimate project cost and schedule performance easily. Although it has been powerful and easy to use, but it can easily misguide contractors, if the cost and schedule inputs data are not correct, and it is not very unlikely. However, mostly in project-oriented companies, corporate's overhead costs are not considered as a part of project costs, and usually are not added to the contract price. Therefore, indices are calculated in the absence of corporate's overhead costs. This non-adding expenditure can impose a great loss (profit) on the company. These costs are not directly spent on a specific project but they are indirectly related to projects due to the supports and services given to the projects. How this additional cost should be added to the project's cost, and how EVM indices should be revised are the questions that this paper answers in the following sections. The difference between regular EVM and the new proposed method are illustrated in Fig. 3.

Budget at completion and actual cost are the basic data needed for EV calculation. In this paper, the difference between Net BAC (NBAC) and BAC is shown using Greek letter Δ. The new BAC would be calculated as follows:

$$BAC = NBAC + \Delta \tag{6}$$

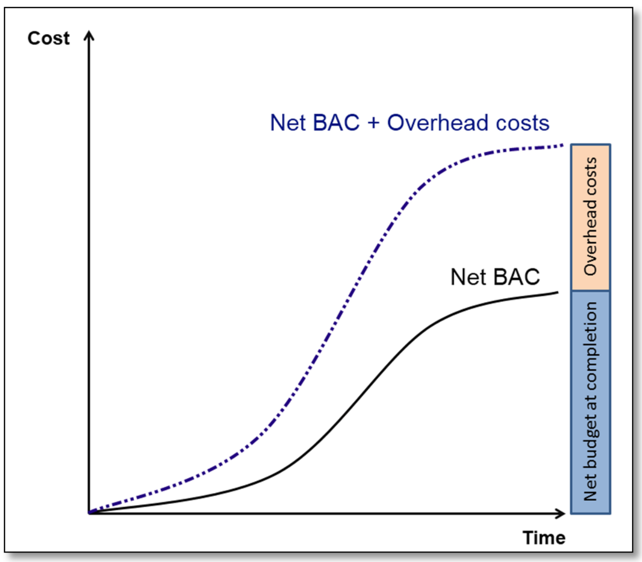

Fig. 3. Project baselines in two different conditions

As Δ was added to BAC, it has to be added to actual cost too. Revised actual cost is as follows:

$$AC_{(r)} = AC + (\Delta \times \mathrm{AP}) \tag{7}$$

By using equation No.6 planned value for a project, subproject, control plan, or phase will be achieved as follows:

$$PV_{(l)} = BAC \times PP_l = (NBAC + \Delta) \times PP_l = PV_{(l)} + (\Delta \times PP_l) \tag{8}$$

And similarly, planned value (PV) and also earned value (EV) of the project would be:

$$PV_{(r)} = BAC \times PP = (NBAC + \Delta) \times PP = PV + (\Delta \times PP) \tag{9}$$

$$EV_{(r)} = BAC \times AP = (NBAC + \Delta) \times AP = EV + (\Delta \times AP) \quad (10)$$

Once $EV_{(r)}$ and $PV_{(r)}$ are extracted, revised Schedule Performance Index (SPI) and Cost Performance index (CPI) can be easily calculated as follows.

Traditionally, the Cost Performance Index (CPI) has been defined as the ratio of earned value (EV) to actual cost (AC). This value will be greater than one, if the budgeted cost is greater than the actual cost of the work performed. In other words, CPI is greater than one when a project is under the budget. This discussion applies to the Schedule Performance Index (SPI) too. It has been defined as the ratio of earned value (EV) to planned value (PV). This value will be greater than one, if the budgeted cost of the work performed is greater than the budgeted cost of the work scheduled. In other words, SPI is greater than one when a project is ahead of schedule.

$$CPI_{(r)} = \frac{EV_{(r)}}{AC_{(r)}} = \frac{EV + (\Delta \times AP)}{AC + (\Delta \times \mathrm{AP})} \quad (11)$$

$$SPI_{(r)} = \frac{EV_{(r)}}{PV_{(r)}} = \frac{EV + (\Delta \times AP)}{PV + (\Delta \times PP)} \quad (12)$$

When the indicators are greater than 1, it does not necessarily mean the project is ahead of scheduling or budget expense, because, it may mean that a mistake has been occurred in planning progress. The following table brings different conditions of $SPI_{(r)}$ and $CPI_{(r)}$.

Table 3
Interpretation of the performance indices

CPI/SPI condition	Meaning	Apparent interpretations	What do they really mean
CPI > 1	EV > AC	By spending less, project gained more.	A conservative baseline by the planners.
CPI < 1	EV < AC	By spending more, project gained less.	Project is not cost effective, because it spent more than it was supposed to.
CPI = 1	EV = AC	Project gained exactly what was planned.	Both project planning and spending procedure have been done without any mistake.
SPI > 1	EV > PV	Project gained more than it was planned for. So the project is ahead of the scheduling.	A conservative baseline by the planners.
SPI < 1	EV < PV	Project gained less than it was planned for. So the project is before the scheduling.	Project is behind the schedule and gains less than it was supposed to.
SPI = 1	EV = PV	Project gained exactly what it was planned for. The project is moving on the scheduling.	Project is progressing exactly on the scheduling as it was supposed to.

Project performance, both in terms of time and costs, is determined by comparing the three key parameters PV, AC and EV, resulting in two well-known performance variances: Schedule Variance (SV) and Cost Variance (CV). The cost and schedule variances tell project manager whether the project is on budget and on-time. Monitoring project variances is critical to ensure if the project is going to be delivered on budget and on time. Cost variance will be negative about projects that are moving over-budget. At the end of the project, the SV index will be equal to 0, because all of the planned value will have been completely earned.

$$CV_{(r)} = EV_{(r)} - AC_{(r)} = CV \quad (13)$$

$$SV_{(r)} = EV_{(r)} - PV_{(r)} = SV - \Delta(PP - AP) \quad (14)$$

In interpreting these indicators, it is important to note that when they are greater than 0, it does not necessarily mean that the project is ahead of scheduling or budget expense. Since it may mean that a mistake has been occurred in planning progress and maybe planners were too conservative. The following table brings different conditions of $CV_{(r)}$ and $SV_{(r)}$. The following table brings cost and schedule variances.

Table 4

Human resources utilized in three projects A, B and C

CV/SV condition	Meaning	Apparent interpretations	What do they really mean
CV >0	EV > AC	By spending less, project gained more.	A conservative baseline by the planners.
CV < 0	EV < AC	By spending more, project gained less.	Project is not cost effective, because it spent more than it was supposed to.
CV = 0	EV = AC	Project gained exactly what was planned.	Both project planning and spending procedure have been done without any mistake.
SV > 0	EV > PV	Project gained more than it was planned for. So the project is ahead of the scheduling.	A conservative baseline by the planners.
SV < 0	EV < PV	Project gained less than it was planned for. So the project is before the scheduling.	Project is behind the schedule and gains less than it was supposed to.
SV = 0	EV = PV	Project gained exactly what it was planned for. The project is moving on the scheduling.	Project is progressing exactly on the scheduling as it was supposed to.

One of the primary tasks of a project manager is making decisions about the future. EVM systems are designed to follow up the performance of a project and to act as a warning signal to take corrective actions in the future. In this regard the most important indicators are: Estimate at completion (EAC) and estimate to complete (ETC) which are functions of time. EAC can be defined as the answer to the question: How much is the likely cost of completing the project? Estimated cost for project completion is named Estimate to Complete (ETC). It is the difference between EAC and ETC. The minimum value of ETC is zero but there is no maximum for it. Neither is there a maximum for EAC. There are some methods for calculating EAC, but in this paper, the main method has been developed as follows.

$$EAC_{(r)} = \frac{BAC}{CPI_{(r)}} = \big(PV + (\Delta \times \mathrm{PP})\big) \times \left(\frac{NBAC + \Delta}{EV + (\Delta \times AP)}\right) \tag{15}$$

$$ETC_{(r)} = \frac{BAC - EV_{(r)}}{CPI_{(r)}} = \big(PV + (\Delta \times PP)\big) \times \left(\frac{NBAC - EV + \Delta(1 - AP)}{EV + (\Delta * AP)}\right) \tag{16}$$

To-complete performance index (TCPI) enables project managers to make suitable decisions and take right corrective actions to finish the project with the planned BAC. It projects the cost performance that the project should have in order to meet the planned BAC or EAC in the remaining time. TCPI can be obtained by dividing the remained work by the remained budget. There are two methods to calculate TCPI. Equations No. 17 and 18 show TCPI based on BAC and EAC, respectively.

$$TCPI_{BAC(r)} = \frac{BAC - EV_{(r)}}{BAC - AC_{(r)}} \tag{17}$$

$$TCPI_{EAC(r)} = \frac{BAC - EV_{(r)}}{EAC - AC_{(r)}} \tag{18}$$

Main EVM indices are developed above with the help of the proposed method. The proposed method in this paper is practical and easy to use. The following section shows successful application of the proposed method in a real-world problem.

6. An Illustrative case

The proposed method is not just a theoretical improvement toward EVM. It is easily applicable to every project and project-based company. With its support, EVM metrics will be calculated more accurate. A numerical illustration is presented to demonstrate how a project-based company with three projects at the same time handles EVM and overhead costs; and consequently it is shown how the proposed method should be implemented.

Consider a multinational civil company with expertise in both construction and water resource management which has started its activity in January 2010. To promote the status of the company, the manager held some seminars, conferences, training courses, workshops and, etc. Company's expenses are listed in Table 5.

Table 5
Company expenses list

1 - Administrative	50000
2 – advertising and Commercial	250000
3 - Training courses	55500
4 - Workshops	100000
5 - Seminars	28000
6 - Conferences	13500
7 - Maintenance	193000
8 - other payments	270000
Total	960000

In the first half of 2011, the company simultaneously started three projects on three different sites. The type and amount of supplies and equipment used in these three projects are shown in the following Tables.

Table 6
Human resources utilized in three projects A, B and C

	Number of staff in project			Working days of each staff in projects			Man-hour of project (8 working hour per day)		
staff type	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1	23	44	12	63	37	40	11592	13024	3840
2	3	6	2	63	37	40	1512	1776	640
3	6	9	0	45	20	0	2160	1440	0
4	4	0	3	27	0	38	864	0	912
5	2	3	1	63	37	40	1008	888	320
6	1	1	1	63	37	40	504	296	320
Total	39	63	19	324	168	198	17640	17424	6032

Table 7
Equipment utilized in three projects A, B and C

	Number of equipment in project			Working days of per equipment in project			Conversion coefficient (αj)			Man-hour of project (8 working hour per day)		
equipment type	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1	2	3	1	40	20	31	8	8	8	5120	3840	1984
2	1	1	3	60	32	30	3	2.5	3	1440	640	2160
3	2	2	2	40	20	31	12	12	12	7680	3840	5952
4	1	0	0	33	0	0	0.5	0	0	132	0	0
5	1	1	4	17	5	38	2.5	2.5	1	340	100	1216
6	2	2	0	11	9	0	10	10	0	1760	1440	0
Total	9	9	10	201	86	130	36	35	24	16472	9860	11312

According to Eqs. (1-4), cost allocation of each of these three projects would be as follows:

Table 8
Overhead cost of each project

	A	B	C	Total
$P_{mh(k)}$	34112	27284	17344	78740
$W_{p(k)}$	0.433223	0.346507	0.220269	1
$OH_{o/p\ (k)}$	415894.3	332647.2	211458.5	960000
$OH_{P(k)}$	34000	19560	13420	66980
$\Delta_{(k)}$	449894.3	352207.2	224878.5	1026980

Other details of the three projects are shown in Table 9 as follows.

Table 9
Details of each project

	A	B	C
Net Budget at completion (BAC)	730580	604200	555920
Actual cost	182600	109760	145020
Planned progress	19%	32%	27%
Actual progress	17%	28%	27%

Now, using Eqs. (6-18), EVM indices are calculated for each project and are compared with the results of regular indices in Table 10.

Table 10
Comparisons between earned value indices for each project both in regular and proposed method for the Company

	project A ($\Delta_{(A)}$ = 449894.3)		project B ($\Delta_{(B)}$ = 352207.2)		project C ($\Delta_{(C)}$ = 224878.5)	
	regular earned value	proposed earned value	regular earned value	proposed earned value	regular earned value	proposed earned value
BAC	730580	1180474.3	604200	956407.2	555920	780798.5
planned progress	19%	19%	32%	32%	27%	27%
actual progress	17%	17%	28%	28%	27%	27%
AC	182600	259082	109760	208378	145020	205737
PV	138810	224290	193344	306050	150098	210816
EV	124199	200681	169176	267794	150098	210816
CPI	0.680	0.775	1.541	1.285	1.035	1.025
SPI	0.895	0.895	0.875	0.875	1.000	1.000
CV	-58401	-58401	59416	59416	5078	5078
SV	-14612	-23609	-24168	-38256	0	0
EAC	1074118	1524012	392000	744207	537111	761990
ETC	891518	1264930	282240	535829	392091	556252
$\boldsymbol{TCPI_{BAC}}$	1.107	1.063	0.880	0.921	0.988	0.991
$\boldsymbol{TCPI_{EAC}}$	0.680	0.775	1.541	1.285	1.035	1.025

The "revised method" columns in the above table, shows what is really going on with these three projects. You can easily see how much earned value indices will change, if Δ is added to the project costs. To discuss the obtained results, consider that Contract prices of projects B and C are revisable while A has a fixed contract price. The owner accepted a term on contract by which from the commencement of the project, the contractor can change the contract prices of B and C, if it is reasonable and defensible. In contrast, as mentioned earlier, A is a project with fixed contract price which the company is supposed to finish and deliver it to the owner with a cost of 1.5 million dollars (i.e. contract price of A: 1,500,000

US$). By looking into traditional EVM indices and metrics, the manager estimates the completion budget about 1070000$ (EAC=1074118$) and consequently estimates the profit about 425882$. Therefore, using regular EVM and not including the company's overhead cost into the contract price, the project manager will be easily misguided. But, results would be different if the manager uses the proposed method where Δ is added to the project cost.

Once again we look into the table, but this time, the proposed method is used to calculate EVM indices. Therefore, project A's overhead costs (summation of project self-generated overhead and allocation from the company), has been 449894.3$. Considering the revised EAC we will find the project is moving beyond contract price. This means not only the project was not profitable, but also it imposed a cost to the company. With the help of the proposed method in this paper, project managers can monitor these aspects of projects more accurately and as a result can make better decisions.

7. Conclusion

The lack of a proper emphasis on the unreliability of cost and schedule performance indices is one of the major causes of failure for many projects; because these indices are the basis for making decisions about the projects. One of the most questionable assumptions of traditional earned value management system is that overhead costs are not included in its calculations. This assignment has explained the central importance of allocating overhead costs, in calculating cost and schedule indices, through the state-of-the-art costing system namely activity based costing. For this allocation, the present study, makes several noteworthy contributions, among which authors suggest that the company's overhead costs should be allocated to projects based on the number of staffs and equipment incurred in general resource pools. Besides new relatively reliable cost and schedule indices have been proposed by which one can well reflect the performance of the project.

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