Journal of

Software Engineering

ISSN 1819-4311

Academic
Journals Inc.

www.academicjournals.com

Journal of Software Engineering 10 (1): 78-88, 2016
ISSN 1819-4311 / DOI: 10.3923/jse.2016.78.88

Software Projects Tracking-Evolving a New Method for Software Project Tracking

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ABSTRACT

In software projects, software development progress tracking against the plan is critical for ensuring success of the project, cost variance, effort variance and time schedule variance do occur during project running and at the closure of project, if these variances are significantly large then this impacts the project success negatively, Thus, it is necessary to monitor these variances and subsequently finding causes and take corrective actions in due time. So, at any point of time, senior project management need to know percentage of completion, cost variance and cost variance is a function of effort variance, to compute effort variance, planned effort at any given point to be known (actual effort is known using time sheets) and in software projects, it is not possible to prepare detailed breakdown information and make this as a part of organization wide central system (many projects running in the organization at the same time) visible to senior project management of the organization. So, a gross level mechanism is needed to know status of the project. This study aims to explore various mathematical methods for progress tracking, limitations of these and evolving a new method for progress tracking. By adopting standard computing methodologies, our research explored and devised a new method for software tracking for computing percentage of completion of project, effort variance and cost variance at any point of time in the absence of availability of detailed and full breakdown information needed for applying earned value management. Using this new method, project variances can be monitored and tracked and thus increasing project success rate by correcting variances. We also take a software project as the application scenario to illustrate our method using obtained results and evidence is analyzed for deriving the final conclusion.

Key words: Software project progress tracking, project management, software project, earned value management, project monitoring and control, method to track software projects

INTRODUCTION

Modern management guru Peter F. Drucker once said "Management is doing things right", in this context, software project management and its key area project monitoring and control need to be done right.

As we know, during a journey, even a map may be useless if we do not know present location and only know target destination. So, in a similar way a project plan is useless if we do not know the current status or unaware about current progress of the project.

To reach to a targeted location, first, we should know current location i.e. how much is being completed so far, so that we can estimate for our targeted journey, software development is also like a journey where at any point of time we need to know the status how much is completed and how much is remaining.

There are numerous challenges in software project management and especially tracking progress of the project and accordingly taking corrective measures for ensuring project success.

In case of software project progress tracking, cost performance index and schedule performance index are two key metrics. Our study is supported by the work of Li *et al*. (2007), the software projects are considered to be successful if the cost and the schedule are within the expected limits and the quality is satisfactory. Therefore, any software project must be executed by balancing the competing demands for quality, schedule and cost. It is crucial to control the actual schedule, quality and cost against the project plan (Li *et al*., 2007). "Three key factors, activity, human and artifact, corresponding to project schedule, cost and product quality, respectively" (Li *et al*., 2007), are key to the success of the project.

The Standish Group International in 2013 reported "that on average only 39% of projects are delivered on time, within budget and with the agreed requirements (therefore those projects perceived as successful). About 43% are delivered late and/or over budget and/or under certain conditions and finally, 18% are cancelled on delivery and never used. More than a decade later, very little seems to have changed." "If at any point in the project, the actual accumulated cost exceeds the earned value of the project at that time, the project is considered over budget, with the shortfall representing a budget overrun" (Patil *et al*., 2012).

Our study supported by, "Earned Value Management Software Projects", IEEE International Conference on Space Mission Challenges for Information Technology (Hanna, 2009), describes and gives insight into earned value management and talked about associating cost with each element and analyzing the variances.

Project Management Institute (PMI) rolled out its second version of the "Organizational Project Maturity Model", This model is called OPM3, "OPM3 offers best practices in software project management across the five maturity levels which could cater for today's project management trends and needs in order for the companies to operate in a multiproject environment" (Ow, 2005).

"It helps to identify the difficulties and the actions that can minimize the uncertainties effects in the projects and how managers and teams can prepare themselves for the challenges of their projects scenario, with the aim of contributing to the improvement of project management in organizations as well as contributing to project success" (Marinho *et al*., 2014).

First, see the well-researched method like Earned Value Management (EVM) technique for tracking projects, lets understand basic EVM elements and their descriptions (PMI., 2005).

Planned Value (PV) describes how far along project work is supposed to be at any given point schedule. It is a numeric reflection of the budgeted work. Earned Value (EV) is a snapshot of work progress at a given point in time. It reflects the amount of work that has actually been accomplished to date (or in a given time period). Actual Cost (AC) is an indication of the level of resources that have been expended to achieve the actual work performed to date (or in a given time period).

Schedule Variance (SV) determines whether a project is ahead of or behind schedule (EV-PV). Cost Variance (CV) shows whether a project is under or over budget (EV-AC), Cost Performance Index (CPI) measures, how efficiently we are using our resources? Earned value and actual cost can also be used to calculate the cumulative Cost Performance Index (CPI), which is one of the clearest indicators of the cumulative cost efficiency of a project. The CPI gauges how efficiently the team is using its resources. It is determined by dividing the Earned Value (EV) by the Actual Cost (AC). In regards to a sample Project EZ, the CPI is:

$$CPI = EV/AC = 32/40 = 0.80 \text{ \{unfavorable\}}$$

Performance measures		Schedule		
		SV>0 and SPI>1.0	SV = 0 and SPI = 1.0	SV<0 and SPI<1.0
Cost	CV>0 and CPI>1.0	Ahead of schedule under budget	On of schedule under budget	Behind of schedule under budget
	CV = 0 and CPI = 1.0	Ahead of schedule on budget	On of schedule on budget	Behind of schedule on budget
	CV<0 and CPI<1.0	Ahead of schedule over budget	On of schedule over budget	Behind of schedule over budget

Fig. 1: Interpretations of basic EVM performance measures (referred from practice standard for earned value management, PMI and PMBOK 4th edition, PMI (2005))

Project management question	EVM performance measure
How are we doing time-wise?	Schedule analysis and forecasting
- Are we ahead or behind schedule?	- Schedule Variance (SV)
- How efficiently are we using time?	- Schedule Performance Index (SPI)
- When are we likely to finish work?	- Time Estimate at Completion (EACT)
How are we doing cost-wise?	Cost analysis and forecasting
- Are we under or over budget?	- Cost Variance (CV)
- How efficiently are we using our resources?	- Cost Performance Index (CPI)
- How efficiently must we use our remaining resources?	- To-Complete Performance Index (TCPI)
- What is the project likely to cost?	- Estimate at Completion (EAC)
- Will we be under or over budget?	- Variance at Completion (VAC)
- What will the remaining work cost?	- Estimate to Completion (ETC)

Fig. 2: EVM and basic project management questions (referred from practice standard for earned value management, PMI and PMBOK 4th edition, PMI (2005))

It is indicated in Fig. 1, CPI less than 1, is over budget, translating into dollars, this means that Project EZ has a cost efficiency that provides, US $0.80 worth of work for every project dollar spent to date (PMI., 2005).

Schedule Performance Index (SPI) (PMI., 2005), measures, how efficiently we are using time? The Schedule Performance Index (SPI) indicates how efficiently the project team is, using its time. The SPI is calculated by dividing the Earned Value (EV) by the Planned Value (PV). For a sample Project EZ:

$$SPI = EV/PV = 32/48 = 0.67 \{unfavorable\}$$

It is indicated in Fig. 1, SPI less than 1 is behind schedule. This schedule performance index indicates that-on average-for each 8 h day. Worked on the project, only 5 h and 20 min worth of the planned work is, being performed; that is, work is being accomplished at 67% efficiency. Various cases of CPI and SPI values and their interpretations are summarized in Fig. 1.

Time estimate at completion using the Schedule Performance Index (SPI) and the average Planned Value (PV) per unit of time, the project team can generate a rough estimate of when the project will be completed, if current trends continue, compared to when it was originally supposed to be completed (PMI., 2005), there are certain questions related to progress of the project which can be answered using PV, EV, AC, SV, SV, CPI, SPI and using these other metrics like time estimate at completion (EACt), To-Complete Performance Index (TCPI), Estimate as Completion

(EAC), Variance at Completion (VAC) and Estimate to Complete (ETC) can be computed, mapping of project questions with EVM metrics are provided in Fig. 2.

The objective of the study is to carry out extensive research towards developing a method to track progress and performance of software projects and eventually facilitating strategic planning to control the progress and making the project successful, hence, the key objectives of the study are:

- Evolving a new method to track software project as an extension of earlier proposed methods as earlier methods are not sufficient to address the problem completely
- Discuss earlier proposed methods/alternatives and their shortcomings
- Understanding the difficulties in applying Earned Value Management (EVM)

MATERIALS AND METHODS

Having introduced to basic elements of Earned Value Management (EVM) technique, now need to understand difficulties in applying Earned Value Management (EVM) technique.

Data source: Data used in this study is taken from Bench marking Release 10 by the International Software Bench marking Standard Group (ISBSG). The ISBSG established in 1994 a not for profit organization that has been established to improve the global understanding of software practices, so that they can be better managed. The ISBSG has gathered on 4,106 software projects from around the world and made available on Release 10 of Estimating, Bench marking and Research Suite CD.

Detailed approach: Now, let's first understand earned value management technique i.e. software project management using Earned Value Management (EVM).

Software project management and tracking using Earned Value Management (EVM) helps project managers to measure project performance. It is a systematic project management process used to find variances in projects based on the comparison of worked performed and work planned. The EVM is used on the cost and schedule control and is very useful in project forecasting. The EVM provides quantitative data for project decision making.

The biggest problem in using EVM technique is, it requires detailed work for tracking, it needed cost estimates for each and every element of the software project which becomes difficult and very extensive for software managers, however large projects can still benefit from it but that too not practiced in software industry. Typical software tools have provision to define project estimates at high level for total planned efforts (person hours), total planned duration and total planned cost instead of computing these for each element of the project and other details of the project.

Software project tracking problem in detail

Background: Project manager or senior project management need to know, if project is currently running on budget and on time, for this cost variance need to be computed and cost variance depends on effort variance so effort variance need to be computed.

To compute effort variance, planned effort at any given point to be known (actual effort is known using time sheets) and in software projects, it is not possible to prepare detailed breakdown information and make this as a part of central system visible to senior project management of the organization. So, a gross level mechanism is needed to know status of the project. Earlier proposed methods has shortcomings, so, a new method needed to be devised.

Detailed problem: When a software project is tracked using any typical project management tracking tool (or simply Microsoft Excel), tool is fed with some basic data i.e. plan start date, plan end date for defining the planned duration of the project, planned efforts i.e. person hours and planned cost then from this at any given point of time, schedule variance, effort variance needs to be computed to arrive at cost variance at any given point of time say on daily basis, weekly basis or fortnightly basis. We know effort invested at any given point of time as time sheets are filled on daily basis in the tool, now if compute effort variance on which cost variance depends, cost variance can be computed. For computing effort variance we needed to know planned effort at any given point of time i.e., effort which have been invested till that point of time.

So, actual effort at any given point of time is known, "Computation of Planned Effort" till a given point of time becomes key challenge and any inappropriate assumptions considered in base data can lead to incorrect computation of this metric.

First understand, what metrics are available or inputted by project in charge.

Pre-set metrics available in tracking tool (or Excel based tracking) are as follow:

- Total planned effort
- Total planned duration (planned start date, planned end date)
- Total planned cost

Input metrics at any given point of time, which a manager is supposed to enter for any given point of time:

- Percentage of completion of project (this can be difficult for a manager to input and may be incorrect at times)
- Status in words-any additional information provided or gross level status

Computed at any given point of time:

- Actual invested efforts (till date), computed as time sheets is filled regularly by entire project team (maintained in Excel/system)
- Percentage of actual invested efforts (till date)
- Percentage of time elapsed (till date), computed using start date and current date

Now based on these available metrics, in order to arrive at effort variance and cost variance at any given point of time, we don't know how much effort should have actually invested for the work being completed or we don't know the earned value as it not directly available (since, we do not have any detailed measures as in EVM).

We need to evolve effective method to determine the performance and address the problem.

RESULTS

Before we proceed and evolve an effective method and provide optimized solution for the problem, having understood the information about plan and past and up to the present situation, we need to understand the few critical parameters of future and additionally capture. How much more effort required? How much more time required? These critical inputs to be collected as a must ingredients.

Now based on these available metrics, in order to arrive at effort variance and cost variance at any given point of time and before discussing novel approach of new method, let's first see how using various possible methods planned invested efforts (till date) is computed and intern used to further compute cost variance percentage of and effort variance percentage:

$$\text{Effort variance (\%) (till date)} = \frac{\text{Effort invested (till date)-Planned efforts (till date)}}{\text{Planned efforts (till date)}} \times 100$$

$$\text{Cost variance (\%) (till date)} = \frac{\text{Effort variance (till date)} \times \text{Unit cost of effort}}{\text{Planned cost (till date)}} \times 100$$

Planned cost (till date) = Planned efforts (till date)×Unit cost
assuming efforts and cost are linearly dependent

Now, if can compute planned efforts (till date), we will be able compute the planned cost (till date) and cost variance, consider the base data, data from timesheet and computed data as shown in Table 1 is provided for few attributes i.e., project name, status (in progress/closed), plan start date, plan end date, total planned efforts and total planned cost.

Now, as project personals have filled timesheet, from this we also have invested efforts (till date), based on this percentage of effort invested (till date) can also be computed as specified in Table 2 and also as we know current date and project start date we can also compute percentage of time elapsed (till date) as shown in Table 2.

Method 1:

$$\text{Effort variance (\%) (till date)} = \frac{\text{Effort invested (till date)-Total planned effort}}{\text{Total planned effort}} \times 100$$

This method will generate huge variance till the very end of the project even in best case of project running on-time and on-cost. This may be suitable to compute variance of the project when project is completed.

When applying this:

$$\text{Effort variance (\%) (till date)} = \frac{153\text{-}488}{488} \times 100 = \text{-}69\%$$

So, this may not be appropriate for in progress projects (Chauhan and Rana, 2015).

Table 1: Information about project ABC, base information

Project name	Status	Plan start date	Plan end date	Total planned efforts	Total planned cost
Project ABC	In progress	5-Feb-11	5-Apr-11	488	1.5

Efforts are given in person hour. Costs are given million$, Source: ISBSG (2011) data (Illustration data generated using ISBSG data)

Table 2: Information about project ABC, information from time sheet/computed information

Invested efforts (till date)	Effort invested (%) (till date)	Time elapsed (%) (till date)
153	31	50
From time sheet	Computed information	

Efforts are given in person hour. Costs are given million$, Source: ISBSG (2011) data (Illustration data generated using ISBSG data)

Method 2:

$$\text{Effort variance (\%) (till date)} = \frac{\text{Effort invested (till date)-Planned invested efforts (till date)}}{\text{Planned invested efforts (till date)}} \times 100$$

Where:

Planned invested efforts (till date) = Completion (%)×Total planned effort

When applying this, planned invested efforts (till date) = 31%×488 = 151

$$\text{Effort variance (\%) (till date)} = \frac{153\text{-}51}{151} \times 100 = 1.3\%$$

Assumption: Efforts are uniformly distributed over entire time period and moreover not feasible for a project manager to input correct percentage of completion. May not be appropriate where underlying assumption is not satisfied, so, need to look forward for a more general method (Chauhan and Rana, 2015).

Method 3:

$$\text{Effort variance (\%) (till date)} = \frac{\text{Effort invested (till date)-Planned invested efforts (till date)}}{\text{Planned invested efforts (till date)}} \times 100$$

Assumption: Assuming schedule variance is due to additional efforts being spent and so effort variance will also be in same proportionate:

Effort variance (%) (till date) = Schedule variance (%) (till date)

Where:

$$\text{Planned invested efforts (till date)} = \frac{\text{Effort invested (till date)}}{\text{((Schedule variance (\%) (till date)/100) +1)}}$$

Applying this method, schedule variance is not available in this case, so difficult to compute in cases where it not available. May not be appropriate where underlying assumption is not satisfied, so, need to look forward for general method (Chauhan and Rana, 2015).

Method 4 (New evolved method)

Reverse calculation of percentage of completion and thus planned efforts till date: Now, having understood the problems with earlier proposed methods, computing percentage of completion is difficult, to overcome this difficulty, let's consider to take another metric as an input i.e., how much more efforts to be invested to complete the project.

Table 3: Information about project ABC, additional input taken

How much more efforts required to complete
505
Additional input

Efforts are given in person hour, Source: ISBSG (2011) data (Illustration data created using ISBSG data)

Table 4: Information about project ABC, computed information

Effort at completion	Completion (%) (till date)	Planned invested efforts (till date)
658	23	113
Computed information		Key computed parameter

Efforts are given in person hour, Source: ISBSG (2011) data (Illustration data generated using ISBSG data)

Table 5: Information about project ABC, variance and parameters completion

Effort variance (till date)	Effort variance (%) (till date)	Cost variance (till date)	Effort at completion	Cost at completion	Cost variance at completion	Cost variance (%) at completion
40	35	0.122	658	2.023	0.523	35

Efforts are given in person hour. Costs are given million$, Source: ISBSG (2011) data (Illustration data generated using ISBSG data)

Now having taken this additional input as shown in Table 3, effort at completion can be computed as shown Table 4:

Effort at completion = Invested efforts (till date) (Table 2)
+More efforts required to complete (Table 3)
= 153+505 = 658, as shown in Table 4

Using this "percentage of completion" of the project can be computed precisely i.e.

$$\text{Completion (\%)} = \frac{\text{Effort invested (till date)}}{\text{Effort at completion}} \times 100 = (153/658)\times 100 = 23.1\%$$

As shown in Table 4, this can be input to method 2 i.e.

Planned invested efforts (till date) = Completion (%)×Total planned effort = 23.1%×488 = 113

Now, we can compute, effort variance (till date):

= Effort invested (till date)-Planned invested efforts (till date)
= 153-113 = 40, as shown in Table 5

Where:

Planned invested efforts (till date) = Completion (%)×Total planned effort

$$\text{Effort variance (\%) (till date)} = \frac{\text{(Effort invested (till date)-planned invested efforts (till date))}}{\text{planned invested efforts (till date)}} \times 100$$

= [(153-113)/113]×100 = 35%, as shown in Table 5

Now, effort variance can lead to compute cost variance knowing the unit level cost.

Cost variance = Effort variance×Unit cost
= Effort variance×(Total planned cost/Total planned efforts)
= 40×(1.5/488) = 0.122, as shown in Table 5

Total planned cost and total planned efforts are given Table 1.
**Unit cost is hourly cost if efforts are given person hours.
As shown in Table 5:

Cost at completion = Effort at completion×Unit cost
= Effort at completion×(Total planned cost/Total planned efforts)
= 658×(1.5/488) = 2.023

Cost variance at completion = Cost at completion-Total planned cost
= 2.023-1.5 = 0.523, as shown in Table 5

$$\text{Cost variance at completion (\%)} = \frac{\text{Cost variance at completion}}{\text{Total planned cost}} \times 100 = (0.523/1.5) \times 100 = 35\%$$

as shown in Table 5.

From the results obtained in earlier methods and this method, this is evident this method is most reliable and suitable.

DISCUSSION

One of the key project objectives to measure project performance effectively at any given point of time, there are numerous techniques available and this area has been well researched over a long period of time. Unfortunately, while many researchers have found methods for tracking software project, there are still a number of important related issues that need to be researched.

"In Earned Value Management (EVM), actual costs are tracked. If at any point in the project, the actual accumulated cost exceeds the earned value of the project at that time, the project is considered over budget, with the shortfall representing a budget overrun" (Patil *et al*., 2012).

Our findings are in line with the finding published by Earned Value Management Software Projects", IEEE International Conference on Space Mission Challenges for Information Technology (Hanna, 2009), which describes and gives insight into earned value management and talked about associating cost with each element and analyzing the variances.

Our method helps, where tracking projects at bird's eye of view and still go down the progress status level in projects and also in situations where Earned Value Management cannot be applied due to its elaborative nature.

Our finding also in line with work listed by "Three-dimensional software development model, called AHA (Activity-Human-Artifact). It combines three key factors, activity, human and artifact, corresponding to project schedule, cost and product quality, respectively" (Li *et al*., 2007).

"On the basis of our model, a project tracking process is developed to guide analysts to locate potential causes for different kinds of variations and effectively correct them in real projects" (Li *et al*., 2007).

Our findings also supported by work listed in "A study on software project tracking and oversight practices among software companies in Malaysia". It conveys "Software companies should

consider the use and adoption of better project management models and best practices to keep up with today's shift from tactical to strategic management in software development" (Ow, 2005).

Our findings are in line with work listed in "An approach related to uncertainty in software projects" which states "It is necessary to understand the areas of uncertainty in a project to be able to contribute to its success" (Marinho *et al*., 2013).

In this, analysis is done with three dimensional view to track schedule performance index, this is more useful for analyzing causal relations between these three dimensional factors and impacts of these but our method see the progress performance and answers a fundamental problem of projects progress tracking rather analyzing relationships among factors and metrics.

CONCLUSION

We can conclude, the best way to the software project progress tracking at any point of time when the project in in-progress stage is, first seeking information how much more effort is required to complete the project in person hours. Having known already invested efforts on the project total efforts at completion can be computed, i.e.,

Total efforts at completion= Invested efforts (till date)+How much more efforts required

Which further used to compute completion (%), i.e.,

$$\text{Completion (\%)} = \frac{\text{Efforts invested (till date)}}{\text{Total efforts at completion}}$$

and thus:

Planned invested efforts (till date) = Completion (%)×Total planned efforts

Having known percentage completion and thus planned invested efforts (till date), effort variance and cost variance can be computed more accurately by:

$$\text{Effort variance (\%) (till date)} = \frac{\text{Effort invested (till date)-Planned invested efforts (till date)}}{\text{Planned invested efforts (till date)}} \times 100$$

Thus, this method is better and gives more accurate information then the earlier methods as shown in results, this is presented as method 4 in results and as suggested by results, it is optimized solution to compute effort variance and hence cost variance and knowing status of progress, corrective measures can be planned as may be required for the project.

Our method is especially useful where numerous projects need to be tracked using a project management tool and yet not missing on accuracy of project status without sufficing the need for detailed work as needed by method like EVM.

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