How does a new set of Earned Value Management schedule control work? A case study in IRAN

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Abstract

One of the most effective project time and cost controlling systems is called Earned Value Management (EVM). This system is applied worldwide in different projects of many kinds. Australia, United States, Canada, United Kingdom, Sweden and Japan were the pioneers of applying this system and new reports show that other countries are joining this list. EVM metrics are the three primary concepts of planned, accomplished and actual work, which are integrated measures of time and costs. A number of researchers have found that the time metrics didn't judiciously refer to the schedule performance of a project. One of the recent improvements to the EVM is the application of new time metrics (Schedule Variance (time) ($SV_{(t)}$) and Schedule Performance Index (time) ($SPI_{(t)}$)), which are based on time units instead of monetary units. A 15-month Iranian pipeline project, called “Ardak-Mashad Water Supply”, was controlled by the EVM in this paper. The stages of applying the EVM in this project are described and the difficulties that the EVM team encountered are also presented. In addition, the paper attempts to clarify the application of common time EVM metrics and compare them with the new set of time metrics to interpret the schedule performance of a project. All satisfactory results of the EVM application, are displayed in this paper.

Keywords: Earned value management, Pipeline Project, Project control

1. Introduction

1.1. Background

EVM (Earned Value Management) has been practiced in different countries for different types of projects. The importance and effectiveness of this method in controlling projects in different industries is undeniable. Basically, the basic concepts of the EVM have been used for over 35 years primarily in the defense contracting industry in the United States [1] and is known as C/SCSC (Cost Schedule Control System Criteria) and it has been applied extensively by a number of agencies of the US Federal Government, particularly for large-scale projects [2]. Meanwhile the EVM has been applied relatively for defense projects in Australia [3]. To introduce this powerful project control mechanism, PMI 2000 became a major milestone for the EVM. In fact, before becoming part of the PMI family, the College of Performance Management supported the EVM regulations and indeed the Project Management Institute conference in Houston was the first to feature a track dedicated to performance management, which was sponsored by the College of Performance Management [4]. Up to the present time, the EVM has been mainly applied by defense organizations for their projects and it has had limited mentions at different conferences. Until 2008, some countries applied the EVM in different ways for a diversity of aims. Australia, as an experienced country in Project Management, pioneered payment by earned value. In America, the United States reflected the application of the EVM in major projects and in its defense acquisition policy while Canada applied the EVM in small projects rather than in preference to larger ones. European countries, such as Sweden and the United Kingdom, also tried to adapt the EVM and its functionality mostly in defense projects. Japan, as a modern Asian country joined the international EVM community through the Ministry of Construction and put its goal and emphasis on using the EVM in construction projects rather than defense projects. These efforts motivated other countries to perform the application of the EVM in their projects mainly defense and construction projects. Abba [4] mentions that the list of the countries which intend to apply the EVM is certain to grow, posing a challenge for those who are directly involved in the EVM to support all the events in a project. "It is exciting to watch new ideas take root in country after country as first government, then industry adopt the EVM model that originated as a contract requirement in the United States Department of Defense [4]".

2. Definition of the EVM

Earned Value Management (EVM) is an integrated system of project management to measure and communicate the real physical progress of a project [5]. This system enables a contractor and his/her customer to monitor the progress of a project objectively and in terms of integrated cost, schedule and technical performance values and to be aware of the status of the project ([2], [6] and [7]). Abba [8] adds that the EVM relates resource planning and usage to schedules and to technical performance requirements. Risk management of the project can be affected by the EVM through measuring project progress in monetary terms, to highlight the possible need for corrective action. The EVM allows objective assessment and quantification of current project performance. The EVM also provides support in forecasting final cost [9]. As a result, effective decision making based on objective, accurate and timely data can be facilitated by the EVM.

2.1. Getting Ready for the EVM

The EVM is not a technique that can be introduced easily by a company or an organization. Indeed, companies need to meet certain criteria before using the EVM as a project management tool. Six criteria mentioned by [10] are needed prior to using the EVM:

1. An organizational structure is needed to permit both cost and schedule performance to be measured by elements of either, or both, structures. e.g. accounting office
2. Schedule the authorized work in a manner that describes the sequence of work and identifies the significant task independencies required to meet the project requirements e.g. work breakdown structure, critical path method
3. Establish and maintain a time-phased budget baseline at the control account level, against which project performance can be measured.
4. Record direct costs in a manner consistent with the budgets in a formal system controlled by the general book of accounts. e.g. detailed activities control
5. At least on a monthly basis, generate reports that compare the amount of planned budget and the amount of budget earned for work accomplished (schedule variance) and the amount of budget earned and the actual direct costs for the same work (cost variance).
6. Provide detailed reasons for schedule and cost variances.

There must be an agreement among executive steering committee, project manager, and project financial analyst on the baseline cost, schedule, and scope of a project. Therefore, the analyst can begin to show planned performance versus actual performance and determine where variances exist, and ultimately, why such variances exist [11].

2.2. The EVM: Metrics

The EVM covers some metrics which should be recognized by a company or organization which intends to apply this method. The use of metrics is important in the EVM. Here, these features are defined in detail. EVM metrics are the three primary concepts of planned, accomplished and actual work, which are integrated measures of time and costs.

2.2.1. Project Plan Metric (PV or BCWS)

A project plan identifies the work to be accomplished. Assessment of this planned work is called Planned Value (PV). The PV is a numeric reflection of the budgeted work that is scheduled to be performed, and it is the established baseline against which the actual progress of the project is measured [12]. The main factor which is related to project plan is Budgeted Cost for Work Scheduled (BCWS) which comprises the total planned costs for all tasks or sub-tasks to be achieved by a given point in time. In fact, the PV is often denoted as the BCWS and in literature either the PV or the BCWS is used.

2.2.2. Project Accomplishment Metric (EV or BCWP)

The metric which quantifies the accomplishment of work is called Earned Value (EV). The EV reflects the amount of work that has actually been accomplished to date, expressed as the planned value for that work [12]. The EV is often used interchangeably with the BCWP. The Budgeted cost for work performed (BCWP) is the total planned costs associated with completed work on tasks or sub-tasks at a given point in time.

2.2.3. Project Actual Metric (AC or ACWP)

One of the main parts of controlling a project's characteristics is controlling the actual costs of the project. Therefore, this amount can be compared with the other above-mentioned amounts in order to apply the EVM method. Actual Cost of Work Performed (ACWP) also known as (AC) is the total expenditure for tasks or sub-tasks at any point in time and as cited by the PMI [12], it is an indication of the level of the resources that have been expended to achieve the actual work performed to date.

Figure 1 presents the three above mentioned EVM metrics for a specific project.

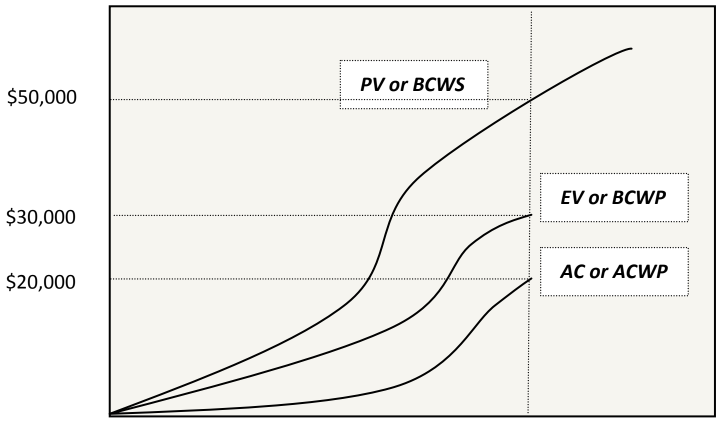

Figure 1. EVM basic Metrics

Consider the following example where the project is a particular activity. If the project's contract is $50,000 valued to date, then PV=$50,000. If the management spent $20,000 up to now, then AC=$20,000. However, if this amount of money has just accomplished 60% of the project, then the earned value is the amount of work that has actually been accomplished to date is $30,000.

2.3. Performing the EVM for Project Analysis

The Planed Value (PV or BCWS), Earned Value (EV or BCWP) and the Actual Cost (AC or ACWP) can be employed to analyze the project's current situation at any time during the project. In fact, Earned Value Management provides four well-known schedule performance indices, the Cost Variance (CV), Cost Performance Index (CPI), Schedule Variance (SV) and the Schedule Performance Index (SPI), all related to the three mentioned metrics, to measure project progress.

2.3.1. Cost Variance

Cost Variance (known as CV) is used to analyze the project in terms of cost performance. A Project manager by using the CV is able to check whether the project is under or over budget. The CV is the result of the following sum.

$$CV = EV - AC \quad (1)$$

In the previous example, CV = $30,000-$20,000=$10,000 (under budget).

2.3.2. Cost Performance Index (CPI)

The Cost Performance Index (CPI) is used as a key measure for analyzing the project cost efficiency. The CPI measures the rate at which value is earned for the actual costs incurred or a measure of the cost efficiency of the work accomplished [11]. As stated by the PMI [12], the CPI gauges how efficiently the team is using its resources. It is the result of the following sum.

$$CPI = EV/AC \quad (2)$$

When CPI>1.0, the project manager finds that the project is currently under budget

On the contrary, when CPI<1.0, the project manager finds that the project is currently over budget

In the previous example, CPI = $30,000/$20,000=1.5 and it means the project is currently under budget.

2.3.3. Schedule Variance (SV)

Schedule Variance (known as SV) is used to analyze the project in terms of time (schedule) performance. The SV enables the project manager to check whether the project is ahead or behind schedule. The SV is the result of the following sum.

SV = EV – PV (3)

In the previous example, SV = \$30,000/\$50,000= -\$20,000 (behind schedule).

2.3.4. Schedule Performance Index (SPI)

Schedule Performance Index (SPI) is used as a crucial measure for analyzing the project efficiency in terms of its schedule. The SPI is the rate of progress against the original schedule with respect to time, or a measure of schedule efficiency of the work accomplished [11]. It is the result of the following sum.

SPI = EV/PV (4)

When SPI>1.0, project manager finds that the project is currently ahead of schedule

On the other hand, when SPI<1.0, the project manager finds that the project is currently behind schedule

In the previous example, SPI = \$30,000/\$50,000=0.6 and it means the project is currently behind schedule.

2.4. Project Final Cost and Time Prediction

The EVM introduces some metrics which are used for prediction of final cost and timing of the project. These metrics are Budget at Completion (BAC), Estimate at Completion (EAC), Variance at Completion (VAC) and Time Estimate at Completion (EAC_t).

2.4.1. Budget at Completion (BAC)

Budget at Completion (BAC) represents total planned project costs as well as a contingency for management reserve.

2.4.2. Estimate at Completion (EAC)

Estimate at Completion represents the sum of all current actual costs plus all remaining costs to complete a task or project. The EAC results from the following sum.

EAC = BAC/CPI (5)

2.4.3. Variance at Completion (VAC)

The metric for a project manager to discover whether the project will finish under or over budget is Variance at Completion or VAC. The VAC is the result of subtraction of the EAC from the BAC.

VAC = BAC – EAC (6)

When VAC>0, project manager finds that the project will finish under budget

On the other hand, when VAC<0, the project manager finds that the project will finish over budget

A noticeable fact is that BAC and EAC both are expressed as monetary terms.

2.4.4. Time Estimate at Completion (EAC_t)

As defined by the PMI [12], Time Estimate at Completion (EAC_t) is a metric which makes a project manager to generate a rough estimate of when the project will be completed if the current trends continue. EAC_t results from the following sum.

EAC = BAC/SPI (7)

2.5. Confusion about the SPI

There are a lot of studies over controlling projects of different kinds by the EVM system. However, there is a complicated issue here. Fleming & Koppelman [13] judge that although the EVM has been setup to follow-up both time and cost, the majority of the research has been focused on the cost aspect. Indeed, there is confusion here about the SPI at the end of the project. At the end of a project when the PV, EV and the BAC equal each other, (PV = EV = BAC), the SV becomes 0. Hence, the SPI becomes dimensionless (Since it is the ratio between the earned value and the planned value, i.e. SPI = EV/PV). To solve this problem, it is suggested that, as the SPI is an indicator to measure the efficiency of the work, the project manager should consider that the SPI is always equal to 1 at the end of the project's duration. However, some researchers have another idea about the time (schedule) metrics used in the EVM system. Lipke et al. [9] mentions that there have been several studies of the behavior of the CPI, however, the SPI is a different matter. Therefore, they developed other time (schedule) related metrics which seem more appropriate. Here, these metrics and their origins are explained.

3. A New EVM Time (Schedule) Metrics

The interpretation and the behavior of the earned value management performance indicators (the SV and the SPI) over time have been criticized by different authors, distinctively ([5]; [9] and [14]), who strongly believe that the EVM schedule indicators (SPI and SV) are not so well studied since they are broadly recognized for being failed when projects continue execution after planned end date. There are three confusing themes here.

- "The SV is measured in monetary units and not in time units, which makes it difficult to understand and is therefore often a source of misinterpretations [5]".
- SV = 0 (or SPI = 1) could mean that a task is completed, but could also mean that the task is running according to the plan.
- For late finishing projects, the SPI converges and concludes at the value 1 while the SV behaves similarly, converging and concluding at 0 indicating 100% schedule efficiency even in the project is late. With this flaw schedule prediction cannot be performed reliably using the SPI.

3.1. Earned Schedule (ES)

To solve the problems mentioned above, some other factors and metrics can be introduced. The main one is the concept of earned schedule (ES). In this method, the earned value at a certain (review) point in time is traced forwards or backwards to the performance baseline (S-curve) or the PV. This intersection point is moved downwards on the X-axis (the time scale) to calculate the earned schedule (ES) [14] (See Figure 2).
Hence, the ES is found by identifying in which time increment of the PV the EV occurs. It translates the EV into time increments and measures the real project performance in comparison to its expected time performance.
Having done the previous sums, it is necessary to calculate the ES. In fact, the ES (when PV = EV occurs) is traced between two time increments (i.e. between 7^{th} and 8^{th} months of a project). The factor "C" is defined as the lesser time increment, which in this case it is 7.
Therefore, C = 7. "I" is also defined as follows:

$$I = (EV - PV_{(C)}) / (PV_{(C+1)} - PV_{(C)}) \quad (8)$$

which in this case the "I" becomes:

$$I = (EV - PV_{(7)}) / (PV_{(8)} - PV_{(7)}) \quad (9)$$

As mentioned by Lipke et al. [9], the ES is defined:

$$ES = C + I \quad (10)$$

3.2. Schedule Variance ($SV_{(t)}$) and Schedule Performance Index ($SPI_{(t)}$)

For analyzing the project in terms of the schedule, Schedule Variance (time) or $SV_{(t)}$ and Schedule Performance Index (time) or $SPI_{(t)}$ are introduced. These two schedule metrics can be defined by the following formulae:

$$SV_{(t)} = ES - AT \quad (11)$$

$$SPI_{(t)} = ES/AT \quad (12)$$

where AT is used to refer to the Actual Time which is the number of time increments corresponding to the EV.

3.3. Merits of the new EVM metrics

There are some benefits in applying the $SV_{(t)}$ rather than the former SV. The most important one is that in contrast to the SV, the $SV_{(t)}$ is expressed in time units, which makes it easier to interpret. It seems more logical and also more reliable for a project manager who intends to interpret this term in the project. Moreover, although Vandevoorde & Vanhoucke [5] mentioned that either the old or the new method might lead to similar results in the project's early and middle stages, they strongly confirmed that the new method makes more sense at the project's final stage and the result are more convincing than the old method.

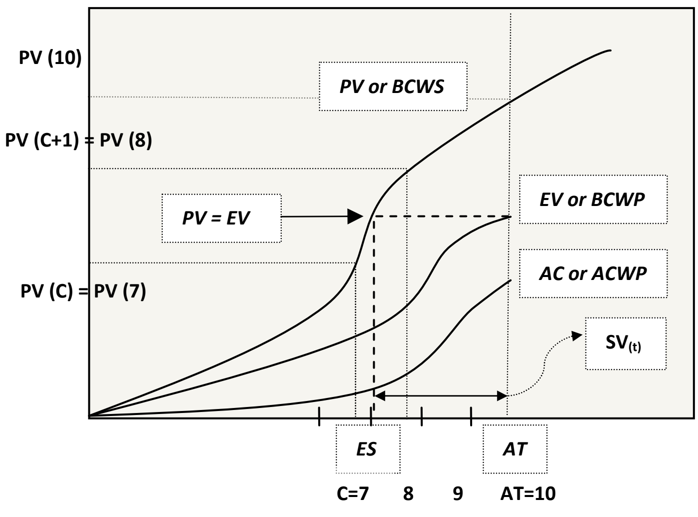

Figure 2. New EVM Schedule Metrics

4. The case study: "Ardak-Mashad" pipeline project

4.1. How to choose the case?

The most important part of this research is to find a case study, which can potentially adopt the EVM. Two subjects were important in this case. First, the research needed an organization, which was capable of adopting the EVM. Secondly, the organization needed to possess a project, which could be controlled regularly.

Some criteria were taken into account when it came to choose a case study. In fact, to apply the EVM in a particular project, as mentioned before, a company needs to possess a project team or even better to possess a project office in order to trace the project cost and time trends. The company also needs to keep a record of its expenditure during the lifecycle of the project and prepare at least monthly reports. Having enough information about the project's cost and time aspects enable the company to analyze the current situation of the project and determine whether it is well controlled at a particular time or not. What is needed for the applying EVM calculations in a project are three sets of information about the planned value, earned value and actual cost of that project.

4.2. Application of the EVM on "Ardak-Mashad" pipeline project

4.2.1. Introduction

A case study needs to be chosen by the researchers and monitored in order to test the EVM theory and particularly the new schedule control. Primarily, a thorough study has been undertaken in order to find suitable case studies. Basically, three case studies were found during this procedure. All of these projects belong to companies, which can potentially adopt the EVM. Among these three projects, which were slightly different in nature, one was chosen for the aim of this paper. The selected case is a project titled "Ardak-Mashad Water Supply" which is a national pipeline project between two cities of "Ardak" and "Mashad" located in Iran. This project has been monitored during the planning and the execution phases. "Toos Abgin" Construction organization, which is authorized to execute this project, decided to apply the EVM in this project in order to manage the "schedule" and the "cost" performance procedure. A team, including the paper authors, has been assigned to trace the cost and the schedule trend of the project and prepare the monthly report which covers monthly project PV, EV and AC.

4.2.2. Organizational change

The papers authors devised a broad plan to help the organization meet the pre mentioned requirements for applying the EVM. First of all, an office was established within the organizational structure, which was supposed to be in charge of controlling the projects (This office is designed to control all in hand projects, which are being undertaken by the organization and this pipeline project is one of those).

4.2.3. Recruiting trained and expert people

In the second step, experts, who used to control different projects, were gathered. They were told to work part-time in that office since they had some other responsibilities in various projects. Almost all these people, then, received some training from the paper authors. This was undertaken to ensure that all of these experts became familiarized with all EVM terms especially the schedule control related issues, which was new.

4.2.4. Reporting the costs

All of the office members were asked to prepare a scheduled record of the project's actual cost and compare it with the budgeted work at the time of record as well as checking it against the planned value of the work, which was finished at that time. Cost and schedule variance calculations needed to be done after all of these comparisons. Then all of the calculations should be reported to the EVM supervising group on a regular time basis (In this case study it was decided that all of these statistics should be reported monthly and in detail).

4.2.5. Results interpretation

The EVM supervising members were also asked to interpret the results of all these calculations and prepare reasons as to why sometimes the results are not as desirable as they should be. To solve this problem and improve the project performance, some actions, which should have been supported by the top managers, were decided by the EVM group. In fact, at this stage, it was very important to establish a close relationship between the organization's executive members, project junior and senior managers and the control office.

4.3. Barriers to EVM application: Finding solutions

The EVM researchers, who intended to apply the EVM on the "Ardak-Mashad" pipeline project, encountered some barriers on their way. Some of these barriers were easy to solve, but some of them, which were related to cultural issues, were basically difficult to overcome.

The first problem was to convince the "Toos Abgin" Construction organization, which was responsible of the project execution phases, that the application of the EVM can influence the efficiency of project control dramatically. Some presentations were held by some junior managers, who were in contact with the paper authors, to prove the benefits of applying the EVM in different previous projects.

The second issue was persuading the organization to allocate a suitable place for the EVM office (or a PMO with less authority). Then it was time to gather a group of expert technical managers of the organization, who were always busy, to keep record of the EVM factors. These people, having a lot of responsibilities in the project, did their best to gather all needed information though.

The most important problem was encountered at the time when the team intended to interpret the result of the EVM calculations. This matter became very controversial as it was difficult to convince the top managers that the project could be sometimes behind schedule or over budget. During the execution phase of the project, the results sometimes showed that the progress was not acceptable and that the cost was higher than what it should have been and this happened while the organization was defending its policy and its way of project control. In order to solve such problems, some meetings were held to show that what the EVM group had prepared was flawless and that the trend was indeed undesirable. By applying the cooperation between the EVM group and the executive managers, both junior and senior, the EVM result became in fact satisfactory. As a result, the top managers of the organization concluded that the EVM calculations were working accurately to control the project time and cost issues. Hence, after a short period of time and long discussions, the organization was convinced to help the EVM group ease the process of gathering the records of project cost. All these issues were recorded by the EVM group as "Lessons Learned Files" in order to apply them in future projects.

4.4. EVM results from the case study

The EVM team had been keeping record of PV, EV and AC for all activities related to this project to the end of the pipeline project. The project comprised of 8 phases, which were supposed to take 15 months. The summary of these costs up to the 10^{th} month of the project is shown in Table 1 to show the reader how the process was undertaken. In the table 1 PV represents budgeted cost for work scheduled, which was developed for the project even before start of the execution phase of the project. EV, which is the major earned value factor, calculated by the EVM team and the result is shown in the forth column. In the last column, the result of actual cost is shown for all of the activities. A very interesting matter is that actual cost of some of the activities was sometimes much less than the planned cost (PV). For example, the actual cost of the activity WA08 after its completion was 340,000,000 Rial less than the planned cost and that was because of changing the sub-contractor for that activity.

In addition, the result of monthly PV, EV and AC reports, which are collected by the EVM team up to the 10^{th} month of the project commencement, are presented in table 2. Although it was the first time to apply this method, surprisingly the actual cost was intended to be kept very close to the scheduled cost and earned value and the result was very satisfactory. By having all information about PV, EV and AC, consequently, the accumulative PV, EV and AC charts (See Figure 3) can be sketched out by the EVM group. This figure is a very helpful device to illustrate the process of controlling corresponding time and cost issues of a project. In fact, by using such a graph, it will be very easy to track PV, EV and AC in order to keep them under control in terms of time and cost.

After depicting the trend of the EVM metrics in a graph, a project manager is able to evaluate all EVM metrics especially CV, CPI, SV, SPI and $SPI_{(t)}$ in order to control schedule and cost of the project. The result of these calculations is also provided in table 3.

Phase	Activities	PV (BCWS) (Rial)	EV (BCWP) (Rial)	AC (ACWP) (Rial)
Phase 1	WA01	34,000,000	34,000,000	25,500,000
	WA02	8,500,000	8,500,000	8,500,000
	WA03	3,400,000	3,400,000	3,400,000
	WA04	3,400,000	3,400,000	3,910,000
Phase 2	WA05	3,400,000,000	3,400,000,000	3,570,000,000
	WA06	6,800,000,000	5,559,000,000	8,500,000,000
	WA07	7,140,000,000	6,290,000,000	7,310,000,000
Phase 3	WA08	7,140,000,000	7,140,000,000	6,800,000,000
	WA09	18,700,000	18,700,000	20,400,000
	WA10	340,000,000	340,000,000	340,000,000
	WA11	187,000,000	170,000,000	190,400,000
	WA12	170,000,000	132,600,000	139,400,000
	WA13	204,000,000	204,000,000	205,700,000
	WA14	136,000,000	102,000,000	137,700,000
	WA15	850,000,000	765,000,000	867,000,000
Phase 4	WA16	5,950,000,000	5,950,000,000	5,952,890,000
	WA17	425,000,000	425,000,000	435,200,000
	WA18	136,000,000	136,000,000	136,000,000
	WA19	76,500,000	76,500,000	79,900,000
	WA20	62,900,000	62,900,000	63,750,000
	WA21	765,000,000	765,000,000	782,000,000
Phase 5	WA22	8,500,000,000	8,500,000,000	8,500,000,000
	WA23	18,700,000	18,700,000	18,700,000
	WA24	13,600,000	11,050,000	12,240,000
	WA25	93,500,000	93,500,000	102,000,000
	WA26	34,000,000	34,000,000	36,550,000
	WA27	25,500,000	25,500,000	25,500,000
	WA28	15,300,000	15,300,000	17,000,000
	WA29	52,700,000	52,700,000	54,400,000
	WA30	1,105,000,000	1,105,000,000	1,105,000,000
Phase 6	WA31	5,780,000,000	5,780,000,000	5,780,000,000
	WA32	47,600,000	47,600,000	47,940,000
	WA33	25,500,000	25,500,000	25,500,000
	WA34	146,200,000	0	0
	WA35	255,000,000	0	0
	WA36	374,000,000	0	0
	WA37	425,000,000	76,500,000	81,600,000
Phase 7	WA38	5,610,000,000	5,610,000,000	5,610,000,000
	WA39	365,500,000	18,700,000	40,800,000
	WA40	20,400,000	0	0
	WA41	136,000,000	0	0
	WA42	204,000,000	0	0
	WA43	425,000,000	68,000,000	73,100,000
Phase 8	WA44	34,000,000		
	WA45	35,700,000		
	WA46	25,500,000		
	WA47	17,000,000		

Table 1. "Ardak-Mashad Water Supply" project PV, EV and AC records of all activities up to the 10th month of the project

Months	PV (BCWS) (Rial)	EV (BCWP) (Rial)	AC (ACWP) (Rial)
1	45,900,000	45,900,000	37,400,000
2	4,930,000,000	4,930,000,000	5,270,000,000
3	10,540,000,000	9,520,000,000	12,240,000,000
4	12,750,000,000	12,070,000,000	14,960,000,000
5	18,870,000,000	16,150,000,000	21,420,000,000
6	25,670,000,000	22,950,000,000	28,390,000,000
7	29,580,000,000	26,945,000,000	32,164,000,000
8	32,810,000,000	31,195,000,000	34,510,000,000
9	35,870,000,000	34,850,000,000	37,400,000,000
10	37,638,000,000	36,805,000,000	38,930,000,000
11	42,160,000,000	NA	NA
12	46,240,000,000	NA	NA
13	51,850,000,000	NA	NA
14	55,913,000,000	NA	NA
15	57,747,300,000	NA	NA

Table 2. "Ardak-Mashad Watter Supply" Project accumulative PV, EV and AC Report up to the 10th month of the project

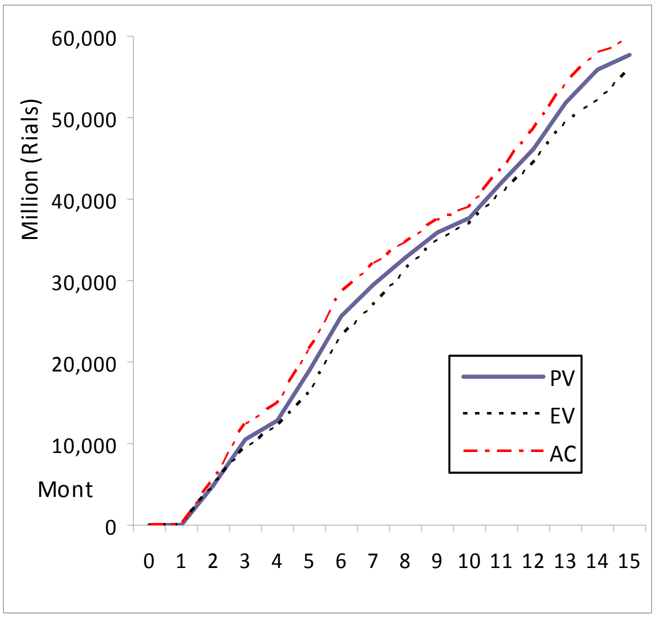

Figure 3. "Ardak-Mashad Water Supply" Project PV-EV-AC Charts

As an example, the condition of the project when it was in its 10th month can be checked in figure 4. By looking at this figure, which demonstrates project PV, EV and AC in 7th, 8th, 9th and 10th months, the EVM metrics can be calculated as follows:

PV (10) = 37,638,000,000 Rial
EV (10) = 36,805,000,000 Rial
AC (10) = 38,930,000,000 Rial

CV = EV – AC ⟶ CV = 36,805,000,000 – 38,930,000,000 = -2,125,000,000 Rial
CPI = EV/AC ⟶ CPI = 36,805,000,000 / 38,930,000,000 = 0.945
It means that the project is over budget

SV = EV – PV ⟶ SV = 36,805,000,000 – 37,638,000,000 = -833,000,000 Rial
SPI = EV/PV ⟶ SPI = 36,805,000,000 / 37,638,000,000 = 0.978
It means that the project is behind schedule

By collecting all relevant data, the new set of schedule metrics can be calculated as follows:

C = 9 Month
AT = 10 Month
$I = (EV - PV_{(9)}) / (PV_{(10)} - PV_{(9)})$ ⟶
I = (36,805,000,000 – 35,870,000,000) / (37,638,000,000 – 35,870,000,000) = 935,000,000 / 1,768,000,000 = 0.529
ES = C + I ⟶ ES = 9 + 0.529 = 9.529 Month
$SV_{(t)} = ES - AT$ ⟶ $SV_{(t)} = 9.529 - 10 = -0.471$
$SPI_{(t)} = ES/AT$ ⟶ $SPI_{(t)} = 9.529 / 10 = 0.9529$

The result of the new time calculations verifies the previous result (SV and SPI). In fact, the result shows that the project is behind schedule, which is similar to the result from the previous method. However, this method is considerably easier to interpret since it is based on time unit.

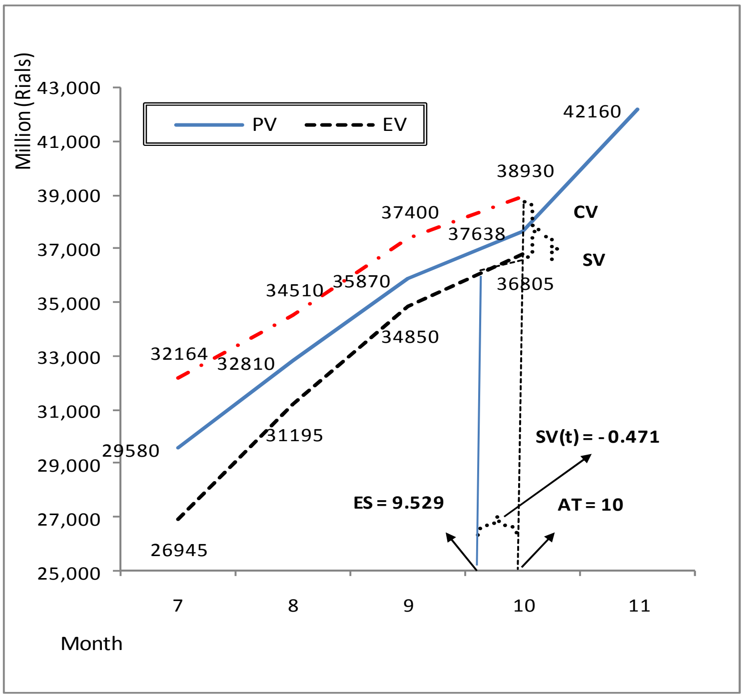

Figure 4. An example for determining the Project $SV_{(t)}$ and $SPI_{(t)}$

The result of all EVM metrics calculations is provided in the following table (Table 3). This table is the main table for judging whether a project is on a right track or not. In fact, whenever the CPI < 1.0, it means that the project is over budget and whenever the $SPI_{(t)}$ < 1.0, it shows that the project is behind schedule.

As table 3 displays "Ardak-Mashad" pipeline project was mostly over budget and behind the schedule for most of the time. The interesting issue in table 3 is the difference of the previous and new sets of time schedules. Both of these sets conclude the same, but the numbers and their sensitivity are slightly different. For instance, the lowest number of SPI, which means that the project is going to be out of time control is in the 5^{th} months (0.856) while the lowest number of $SPI_{(t)}$ is in the 7^{th} month (0.904).

Months	CV (Rials)	CPI	Result	SPI	SV(t) (Month)	SPI(t)	Result
1	8,500,000	1.227	Under budget	1.000	0	1.000	On time
2	-340,000,000	0.935	Over budget	1.000	0	1.000	On time
3	-2,720,000,000	0.778	Over budget	0.903	-0.18182	0.939	Behind schedule
4	-2,890,000,000	0.807	Over budget	0.947	-0.30769	0.923	Behind schedule
5	-5,270,000,000	0.754	Over budget	0.856	-0.44444	0.911	Behind schedule
6	-5,440,000,000	0.808	Over budget	0.894	-0.4	0.933	Behind schedule
7	-5,219,000,000	0.838	Over budget	0.911	-0.67391	0.904	Behind schedule
8	-3,315,000,000	0.904	Over budget	0.951	-0.5	0.938	Behind schedule
9	-2,550,000,000	0.932	Over budget	0.972	-0.33333	0.963	Behind schedule
10	-2,125,000,000	0.945	Over budget	0.978	-0.47115	0.953	Behind schedule
11	-2,958,000,000	0.932	Over budget	0.966	-0.31955	0.971	Behind schedule
12	-3,893,000,000	0.919	Over budget	0.961	-0.4375	0.964	Behind schedule
13	-4,760,000,000	0.912	Over budget	0.954	-0.42424	0.967	Behind schedule
14	-5,865,000,000	0.899	Over budget	0.933	-0.92887	0.934	Behind schedule
15	-3,672,000,000	0.938	Over budget	0.967	-1.0278	0.931	Behind schedule

Table 3. "Ardak-Mashad Water Supply" Project EVM Parameters Calculations

5. Summary

This paper presents the application of the Earned Value Management (EVM) in controlling the cost and time performance of an Iranian pipeline project called "Ardak-Mashad Water Supply". Basically, the common EVM metrics were calculated using all of the cost related records. In addition, a new set of EVM metrics, which were suggested by other researchers, has been practiced in this project. Therefore, it is more convincing to compare the previous method with the new ones. These new metrics, which are used for controlling the time

performance of the project, are time based rather than being monetary based so that they can be interpreted more reasonable than the common schedule metrics.
Also, different stages of the EVM application in “Ardak-Mashad Water Supply” project are described briefly in the paper to show how the authorities supported the EVM group to control the time and cost related issues of the project. Basically, an office was established for the EVM team and then some experts were employed part time to work in the EVM team. They were then trained to work with the EVM and were finally told to provide a monthly report of the project cost and to calculate the earned value results. After all of these stages, the EVM team could interpret the results and advise the top managers to control the project in terms of time and cost.
After all, the results show that this project is generally over budget and behind schedule. Apart from the result, it made the project managers aware of the current situation of the project so that the managers could manage the project expenditure in a more reasonable way and improve project time and cost efficiency. In fact, the monthly report of the EVM calculation was like a lever for the project to ease the authority's management. It gives time to the managers to devise a new plan when the project is over budget or behind schedule. Therefore, the managers can make the project within the budget and on time when they are aware of the deficiencies or at least prevent the project from being in a worse condition.

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