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EARNED SCHEDULE MANAGEMENT AS A COMPLEMENT FOR EARNED VALUE MANAGEMENT

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Earned Value Management is a well-known technique within project management, which allows to control and forecast the project based on your budget and its degree of execution. However, the behavior of this tool has a more significant significance from 20% of the project's progress.

Many of their indicators are calculated in terms of cost and have been shown to perform poorly in the final stages of the project, showing a correct behavior when the project is delayed. Earned Schedule Management is an "evolution" of Earned Value Management that solves this deficiency.

Keywords: *Earned Value Management; EVM; Earned Schedule Management; ESM; monitoring and controllingl; forecasting*

GESTIÓN DE LA PROGRAMACIÓN GANADA COMO COMPLEMENTO A LA GESTIÓN DEL VALOR GANADO

La Gestión del Valor Ganado es una técnica ampliamente conocida dentro de la gestión de proyectos, que permite controlar y pronosticar el proyecto a partir de su presupuesto y su grado de ejecución. Sin embargo, el comportamiento de esta herramienta tiene una significancia más considerable a partir del 20% de avance del proyecto.

Muchos de sus indicadores se calculan en términos de coste y se ha demostrado que se desempeñan mal en las etapas finales del proyecto, mostrando un comportamiento correcto, cuando el proyecto está retrasado. La Gestión de la Programación Ganada es una “evolución” de la Gestión del Valor Ganado que solventa esta deficiencia.

Palabras clave: *Gestión del Valor Ganado; EVM; Gestión de la Programación Ganada; ESM; seguimiento y control; pronóstico*

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1. Introduction

In December 1967, the United States Department of Defence (DoD) issued a directive for private industries who wanted to apply in its major procurement programmes or incentives with 35 Cost/Schedule Control Systems Criteria, C/SCSC, that means standards of compliance. Other government agencies in the United States, as well in other nations such as Australia, Canada, Sweden, etc. adopted similar earned-value criteria in the management of their major system acquisitions (Fleming and Koppelman 2010, 1998).

The concept appears in early 1900s and came from industrial engineers in factories who for years have employed a three-dimensional approach to assess true “cost-performance” efficiencies (Fleming and Koppelman 1998). These dimensions consists in:

1. Comparison between earned standards or factory outputs and incurred costs.
2. Comparison between earned standards and original planed ones, to assess the schedule results.
3. Cost variance as the difference between the actual costs spent and the earned standards in the factory.

Earned Value Management (EVM) is a project management technique that allows you to control the execution of a project through its budget and its execution schedule and relates the resource planning, use of schedule and technical performance requirements (Abba 1997).

If the literature is reviewed you can be seen some controversy. On the one hand authors who find the methodology very useful (Kim, Wells, and Duffey 2003; Fleming and Koppelman 1998), while on the other hand others find deficiencies (Arthur 1983; Lukas 2008; Pajares Gutiérrez and López Paredes 2007). On a more generic level, some of these are: quality is never considered, planned value is the baseline and is calculated from uncertain predictions, high implementation costs or high effort to capture current cost data, especially in large projects.

Earned Value Analysis loses predictive capacity at the end of the project. This happens because as the project progresses, the earned value tends to the planned value. In fact, when the project ends, both values must match. To overcome this deficiency, Lipke proposes in 2003 the concept of "**earned schedule**" (Lipke 2003). Other issue to notice is the learning effect that takes place throughout the life cycle of the project (Pajares Gutiérrez and López Paredes 2007). Other point to consider is the morphology of the network. The predictive capacity of the earned value, as well as the earned scheduled, in strongly influenced by this morphology (Vanhoucke and Vandevoorde 2005, 2006).

In the planning phase, costs or time estimations are static, and afterword in the executing phase the management need a flexible perspective. Applying simulations by incorporating the aforementioned flexibility into the models, cost and time estimates are obtained that are significantly different from those provided by the static models (Jørgensen and Wallace 2000). Also, the methodology needs to integrate activity sensitivity information for time forecasting (Elshaer 2013).

An alternative for the model introduces earned duration management, where schedule performance is calculated from metrics expressed in time units, and not in cost units (Khamooshi and Golafshani 2014).

The Earned Value Management is developed under conditions without uncertainty and that by introducing variability in the model, the project manager can know if the deviations of the planned values are in accordance with the statistical variability (Acebes, Pajares, and López-Paredes 2011; Acebes 2015; Acebes et al. 2014; Williams 1992, 1993).

2. Overview of the Concepts of Earned Schedule

The concept of the earned schedule is analogous to the earned value. However, instead of using cost to measure the performance of the schedule, it would use time. The next points describe the basic glossary[1].

The Earned Value Management (EVM) is based on four key variables:

- *Planned Value (PV)*: The authorized budget assigned to scheduled work as of a given reporting date.
- Actual Cost (AC): The realized cost incurred for the work performed on an activity during a specific time period.
- *Earned Value (EV)*: The measure of the work performed, expressed in terms of the budget authorized for that work.
- *Budget at Completion (BAC)*: The sum of all the budgets established for the work to be performed on a project, work breakdown structure component, control account, or work package.

Considering them, the Earned Value Management allows analyse the project performance in the two levels, cost and schedule:

- *Cost Variance (CV)*: The amount of budget deficit or surplus at a given point in time.
- *Schedule Variance (SV)*: A measure of schedule performance on a project. It is the difference between the earned value and the planned value.

  For these both indicators a value equal to or greater than zero indicates a favourable condition and a value of less than zero indicates an unfavourable condition.
- *Cost Performance Index (CPI)*: A measure of the cost efficiency of budgeted resources expressed as the ratio of earned value to actual cost.
- *Schedule Performance Index (SPI)*: A measure of schedule efficiency on a project. It is the ratio of earned value to planned value.

  As in the previous indicators, a ratio equal to or greater than one indicates a favourable condition and a value of less than one indicates an unfavourable condition.

In parallel, the Earned Schedule Management (ESM) starts from two variables:

- *Actual Time (AT)*: The number of time periods from the start of the project to the project status date.
- *Earned Schedule (ES)*: It measures the scheduled work accomplished, expressed in the time based unit of measure being utilized.
- *Planned Duration (PD)*: The planned duration for the project.

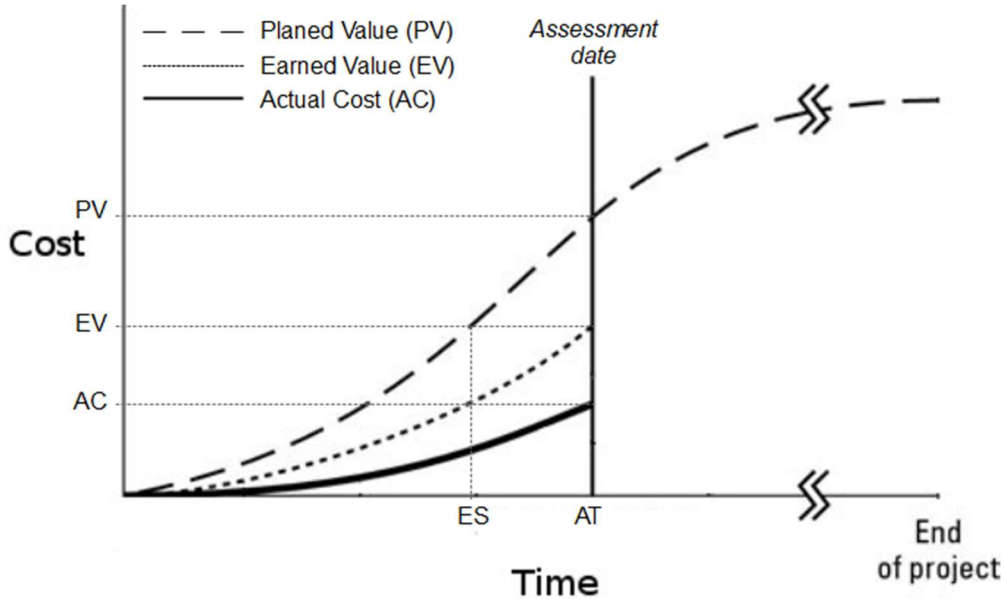
The equation (1) represents the way to calculate the earned value, where *n* is the longest period which $PV_n \leq EV$.

$$ES = n + \frac{EV - PV_n}{PV_{n+1} - PV_n} \quad (1)$$

The Figure 1 shows these variables. The earned value (EV) for the assessment date, which represent the actual time (AT), projected in the planed value curve provides the measure of the earned schedule.

[1] The shown definitions come from the Practice Standard for Earned Value Management (PMI 2005)

Figure 1: Main variables of the earned value and earned schedule for an assessment date.



With these, the method analyses also the project performance with the next indicators:

- *Schedule Variance (time) (SV_t)*: A measure of schedule performance on a project calculated using earned schedule.

  A value equal to or greater than zero indicates a favourable condition and a value of less than zero indicates an unfavourable condition and will only revert to zero at project completion if on-time completion has been achieved.

- *Schedule Performance Index (time) (SPI_t)*: A. measure of time-based schedule efficiency on a project calculated using earned schedule. It is the ratio of earned schedule to actual time.

  A SPI_t equal to or greater than one indicates a favourable condition and a value of less than one indicates an unfavourable condition. The SPI_t will only revert to one at project completion if on time completion has been achieved.

Table 1. Parallelism for the calculation of SV and SPI in the EVM and ESM perspectives.

	EVM	ESM
Schedule Variance	$SV = EV - PV$	$SV_t = ES - AT$
Schedule Performance Index	$SPI = {}^{EV}/_{PV}$	$SPI_t = {}^{ES}/_{AT}$

The Table 1 shows the parallelism in the calculation of the schedule variance and schedule performance index in the both perspectives. Bearing in mind, that in case of the schedule variance the unit of measure for the Earned Value Management is monetary, while for Earned Schedule Management is time.

As the project progresses, forecasts can be developed for cost and schedule performance. Common forecasting items in Earned Value Management includes:

- *Estimate at Completion (EAC)*: The expected total cost of completing all work expressed as the sum of the actual cost to date (AC) and the estimate to complete (ETC).
- *Estimate to Complete (ETC)*: The estimated cost of completing the remaining work.

- *Variance at Completion (VAC)*: A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion (BAC) and the estimate at completion (EAC).
- *To-Complete Performance Index (TCPI)*: A measure of the cost performance that must be achieved with the remaining resources in order to meet a specified management goal, such as the EAC or the BAC.

  In this case, a value greater than one indicates an unfavourable condition and a value equal to or less than zero indicates a favourable condition.

As before, by transferring these ratios to Earned Value Management, the forecasting indicators are:

- *Estimate at Completion (time) (EAC_t)*: The expected total time of completing project work. It is equal to the actual time plus the estimate to complete (time) for the remaining work.
- *Estimate to Complete (time) (ETC_t)*: The estimated duration of completing the remaining work.
- *Variance at Completion (time) (VAC_t)*: The difference between the planned duration assigned to a project.
- *To-Complete Schedule Performance Index (TSPI)*: The calculated projection of schedule performance that must be achieved on remaining work to meet a specified goal, such as the EAC_t or the planed duration calculated using earned schedule.

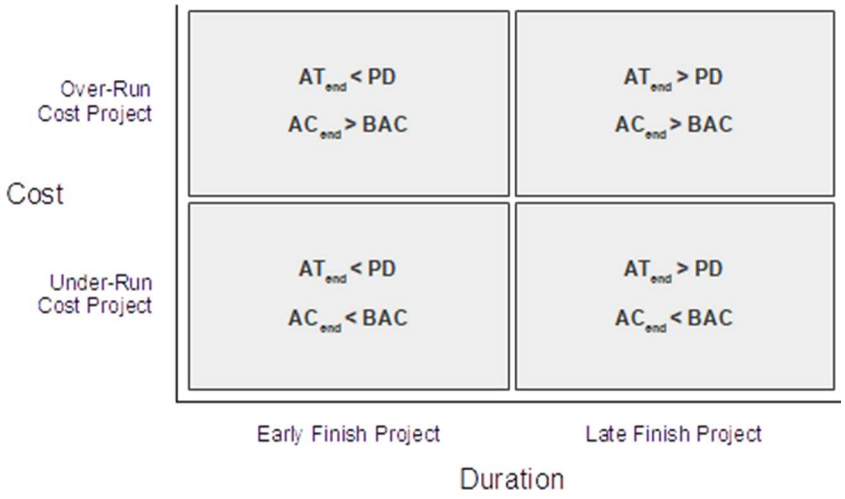
3. Application to Real Projects

As previously mentioned, the schedule variation (SV) and the schedule performance index (SPI) behave erroneously in the final stage of a project, and this is even worse when we know that the project has finished more late than expected, since these indicators indicate that the project has been completed as planned when in reality it is not so.

Lipke (2003) considers two special cases: Early Finish Project and Late Finish Project, in order to introduce the Schedule Value Management. Later on, Vandevoorde and Vanhoucke (2006) in their conducted analysis about this methodology differentiate also when projects under-run and over-run cost.

Following this classification, the Figure 2 shows the different situations, considering if the actual time at the end (AT_{end}) of the project exceeds or not the planed duration (PD) and if the actual cost at the end (AC_{end}) exceeds or not the budget at completion (BAC).

Figure 2: Classification of projects according to cost and time situation.



The Earned Value Management was applied in three different projects related to aeronautical industry, as shown in the Table 2. These can be located in the upper right area of the Figure 2.

Table 2. Project portfolio.

		Cost (€)		Time (months)	
Project	Classification	BAC	AC_{end}	PD	AT_{end}
Implementation of procurement procedure	Late Finish Over-Run Cost	650,000	697,125	12	13
Standardization of KPIs and reports	Late Finish Over-Run Cost	1,150,000	1,497,990	12	16
Implementation of improvement for final assembly line (FAL) for a commercial plane	Late Finish Over-Run Cost	2,250,000	2,742,425	12	18

The three projects are of late completion. As mentioned previously, the accuracy and reliability of the earned schedule metrics can be clearly seen when the project has finished later than expected, since in this case the schedule performance indicators of the Earned Value Management show incorrectly that the project has been completed on time when in reality it is not true. This does not mean that Earned Schedule Management cannot be applied to projects of early completion, since as we have seen previously, it can be applied to any type of project as with Earned Value Management.

It can also be observed that the three projects end with an over-run cost, although in this case it is irrelevant for the purpose of this research, since we are only analysing the performance of the schedule indicators. The earned value metrics are only applicable for the time variable, so it is irrelevant that the project has finished with a low budget, as planned or with an excess of budget.

The first project corresponds to the implementation of procurement procedure, the second one to the standardization of KPIs and reports in the project management office and the third one to the implementation of improvement for final assembly line (FAL) for a commercial aircraft.

The Table 3 shows the calculated data for the schedule performance indicators of the Earned Value Management, as well as of Earned Value Management, which are the most interested to verify the reliability of this last methodology.

Table 3. Schedule indicators for the first project.

Period	SV	SPI	n	ES	SV_t	SPI_t
1	-975	0.93	0	0.93	-0.08	0.93
2	-10,010	0.85	1	1.81	-0.19	0.90
3	-17,875	0.88	2	2.77	-0.23	0.92
4	-18,850	0.90	3	3.64	-0.36	0.91
5	-52,065	0.83	4	4.53	-0.47	0.91
6	-85,020	0.76	5	4.64	-1.36	0.77
7	13,780	1.04	6	7.27	0.27	1.04
8	21,645	1.05	7	8.56	0.56	1.07
9	38,220	1.08	8	9.37	0.37	1.04
10	-23,985	0.96	9	9.77	-0.23	0.98
11	-35,425	0.94	10	9.97	-1.03	0.91
12	-31,655	0.95	11	11.03	-0.97	0.92
13	0	1.00	12	12.00	-1.00	0.92

As can be seen, the same thing happens as previously mentioned for late finish projects. The indicators of Earned Value Management, SV and SPI, show the values 0 and 1, respectively, indicating a perfect completion, when we know that this is not the case, while the indicators of the Earned Schedule Management, SV_t and SPI_t, indicate the values -1 and 0.92, respectively, that if they show really what is happening, since project has finished a month later than planned.

In the same way, the Table 4 and Table 5 show the data for the second and third project. As in the case of the first project, the indicators SV and SPI indicate the values 0 and 1, respectively, while the indicators SV_t and SPI_t show the values -4 and 0.75 in the second project (Table 4) and -6 y 0.67 for the last one (Table 5), as we already intuited at the beginning. Therefore, earned schedule indicators show what is really happening, that is why they have greater reliability, in addition to giving results in units of time and not in monetary units as it happens with the schedule indicators of the Earned Value Management.

Table 4. Schedule indicators for the second project.

Period	SV	SPI	n	ES	SV_t	SPI_t
1	2,415	1.04	1	1.02	0.02	1.02
2	-8,855	0.95	1	1.91	-0.09	0.96
3	-61,755	0.79	2	2.51	-0.49	0.84
4	-112,585	0.73	3	3.02	-0.98	0.76
5	-133,515	0.74	3	3.74	-1.26	0.75
6	-161,920	0.74	4	4.55	-1.45	0.76
7	-125,465	0.82	5	5.61	-1.39	0.80
8	-158,010	0.80	5	5.93	-2.07	0.74
9	-234,600	0.74	6	6.51	-2.49	0.72
10	-255,875	0.74	7	7.13	-2.88	0.71
11	-269,215	0.75	8	8.05	-2.95	0.73
12	-291,870	0.75	8	8.60	-3.40	0.72
13	-238,855	0.79	9	9.04	-3.96	0.70
14	-170,085	0.85	10	10.03	-3.97	0.72
15	-77,510	0.93	11	11.16	-3.84	0.74
16	0	1.00	12	12.00	-4.00	0.75

Table 5. Schedule indicators for the third project.

Period	SV	SPI	n	ES	SV_t	SPI_t
1	22,470	1.19	1	1.17	0.17	1.17
2	44,965	1.18	2	2.23	0.23	1.11
3	-40,774	0.91	2	2.79	-0.21	0.93
4	-307,800	0.62	3	3.14	-0.86	0.78
5	-315,031	0.68	3	3.58	-1.42	0.72
6	-247,623	0.77	4	4.18	-1.82	0.70
7	-337,572	0.74	4	5.00	-2.00	0.71
8	-468,274	0.69	5	5.60	-2.40	0.70
9	-521,360	0.69	6	6.38	-2.62	0.71
10	-517,310	0.72	7	7.11	-2.89	0.71
11	-644,754	0.69	7	7.71	-3.29	0.70
12	-684,900	0.70	8	8.30	-3.70	0.69
13	-532,575	0.76	9	9.14	-3.86	0.70
14	-406,125	0.82	9	9.95	-4.05	0.71
15	-284,400	0.87	10	10.46	-4.54	0.70
16	-176,625	0.92	10	10.90	-5.10	0.68
17	-72,900	0.97	11	11.52	-5.48	0.68
18	0	1.00	12	12.00	-6.00	0.67

4. Conclusions

With the development of the Earned Value Management, different authors indicate that the schedule indicators behave erroneously, especially in the final stage of a project. For this reason, project managers consider that cost indicators are more reliable than schedule ones.

As a result of this problem, in 2003 Lipke proposed a new method for calculating the schedule indicators, called "Earned Schedule". As I have shown throughout the document, these earned schedule indicators are more reliable and accurate than the correspondents in the Earned Value Management.

So much has been the impact of the Earned Schedule Management that the Project Management Institute (PMI) has included it in its book "Practice Standard for Earned Value Management", explaining the concept of earned schedule and how to calculate it.

Throughout these almost fifteen years, since the conception of the earned schedule concept, numerous researchers have been carried out to verify the accuracy and applicability of this new method.

It is not intended that this new method, Earned Schedule Management, replaces Earned Value Management, but that both methods are used together.

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