Analytical Model Implementing Objectives in EVM for Advanced Project Control

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1 Introduction

In such a global industrial market as the current one, competitiveness is a key driver for success. This competitiveness requires the application of the latest technological advances in several fields as, for example, market analysis, manufacturing, management and new information systems. Science and technology go forward generating knowledge by means of the formulation of analytical models that could explain the real behavior of a system and could forecast its future behavior.

Project management is one of the Science disciplines which have experienced a bigger development generating methods and models to increase the efficiency of the definition and launching into the market of products and services, making project management indispensable for business results.

Aligned with this line of thinking, the top technology industries as, for example, aerospace and aeronautics, and government agencies such as NASA, have been exponentially empowering the project management discipline and have been generating guidelines and methods for its development. In parallel, international associations of project managers such as the Project Management Institute (PMI) or the International Project Management Association (IPMA) have been created, and are developing project management competencies interacting with thousands of practitioners and developing relationships with corporations, government

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agencies, universities and colleges, as well as training organizations and consulting companies.

In project management, project control has been developed to define the most efficient indexes showing the current project status and predicting the future scenario. Project control has experienced a quantum leap forward with the irruption of the analytic method of Earned Value Management.

The EVM is one of the project management techniques more used in the world nowadays. In 1965, the United States Air force acquisition managers defined 35 criteria which capture the essence of earned value management. In 1998, it was termed as the ANSI/EIA-748 Standard, and afterwards it has been developed exponentially. Advanced progressing upon EVM standards last research lines concepts have included objectives accomplishment measurement or the probabilistic analysis. Also in recent years, the business value is clearly oriented to the objectives accomplishment; correct definition, control and assessment of the objectives could mean the difference between the project success or failure. As it is explained in the technical universities, a project consisting in developing a new smartphone can be finished on schedule and cost according to the plan but if when the client has the phone on his hands the battery only lasts 30 s, probably the technical objectives are not fulfilled and the product acceptance in the market cannot be the expected!

The contribution of this work is to present a formulation for integrating the project objectives follow up using EVM and giving the managers a practical tool to control the projects in all aspects.

2 Enhancing Business Value with Advanced Project Management

2.1 Advanced Earned Value Management

EVM is a project management powerful technique used to measure and communicate the real progress of a project integrating the scope, schedule and cost, in monetary terms. EVM is a tool used by program managers to: (1) quantify and measure program/contract performance, (2) provide an early warning system for deviation from a baseline, (3) mitigate risks associated with cost and schedule overruns, (4) provide a means to forecast final cost and schedule outcomes. The EVM is well explained in literature, and it is possible to have a very good approach in the references [1].

Historically, it started by industrial engineers on the factory floor in the early 1900s [2], who for years have employed a three-dimensional approach to assess true "cost-performance" efficiencies. To assess their cost performance, they compared their earned standards (the physical factory output) against the actual cost incurred. Then, they compared their earned standards to the original planned standards (the physical work they planned to accomplish) to assess the schedule results. These efforts provided earned value in its most basic form. Most important, the industrial engineers defined a cost variance as the difference between the actual costs spent and the earned standards in the factory. This definition of a cost variance is perhaps the indication to determine whether one uses the earned-value concept.

In 1965 the United States Air force acquisition managers defined 35 criteria which capture the essence of earned value management. Two years later the U.S. Department of Defense (DoD) adopted these same criteria as part of their Cost/Schedule Control Systems Criteria (C/SCSC). Then, in 1996, after a rewrite of the C/SCSC 35 criteria by private industry, the DoD accepted the rewording of this criteria under a new title called Earned Value Management System (EVMS), and the total number of criteria was reduced to 32.

In 1998, National Defense Industrial Association (NDIA) obtained acceptance of the Earned Value Management System in the form of the American National Standards Institute, termed the ANSI/EIA-748 Standard, see [3].

In 2000, The Project Management Institute's (PMI's) A Guide to the Project Management Body of Knowledge (PMBOK Guide) [1] provided the basic terminology and formulas of EVM, and more details were provided in subsequent editions of the PMBOK Guide.

The private sector and the academic investigation have also shown great interest in applying EVM in recent years thanks to numerous publications promoting EVM principles and advanced project management software packages that incorporate EVM methods and analysis [4–6].

The development of the EVM in the last 10 years leads to an enhancement of the EVM from the standard defined in the ANSI/EIA-748 [21, 22]. Nowadays, the main EVM research lines are the following: the reliability assessment of the EVM indexes and forecasting methods of project final duration and cost [7–9, 23, 24]; the EVM extension called Earned Schedule [10, 11]; the consideration of project risks [12, 13]; the integration of the technical performance in the EVM [14–17]; and the use of fuzzy techniques and analytical curves for the EV determination [18, 25].

In order to explain the approach of EVM implementing objectives, first, EVM fundamentals overview will be given. The EVM is based on three basic metrics, Planned Value (PV), Actual Cost (AC) and Earned Value (EV) from which performance indexes and forecasting formulas are constructed.

The EVM variances are shown in Eqs. (1) and (2).

$$\mathbf{CV} = \mathbf{EV} - \mathbf{AC} \tag{1}$$

$$\mathbf{SV} = \mathbf{EV} - \mathbf{PV} \tag{2}$$

The EVM performance indexes are shown in Eqs. (3) and (4).

$$\mathbf{CPI} = \mathbf{EV}/\mathbf{AC} \tag{3}$$

$$\mathbf{SPI} = \mathbf{EV}/\mathbf{PV} \tag{4}$$

The EVM forecasting formulas provide calculations for the Cost Estimate at Completion (EAC) and the Time Estimate at completion (TEAC), based on three different assumptions:

– The assumptions underlying the original estimation are wrong, or no longer applicable due to changed conditions affecting the activity, work package, or project, a new Cost Estimate To Complete (ETC) and Time Estimate To Complete (TETC) need to be developed.

$$\mathbf{EAC} = \mathbf{AC} + \mathbf{ETC} \tag{5}$$

$$\mathbf{TEAC} = \mathbf{AT} + \mathbf{TETC} \tag{6}$$

– Past performance is not a good predictor of future performance, which problems or opportunities which affected performance in the past will not occur in the future, and that future performance will parallel the original plan. Bugdet At Completion (BAC), Baseline Schedule At Completion (SAC).

$$\mathbf{EAC} = \mathbf{AC} + \mathbf{BAC} - \mathbf{EV} \tag{7}$$

$$\mathbf{TEAC} = \mathbf{SAC} - \mathbf{TV} \tag{8}$$

– Past performance is a good predictor of future performance, that performance to date will continue into the future.

$$\mathbf{EAC} = \mathbf{AC} + \mathbf{BAC} - \mathbf{EV}/\mathbf{CPI} \tag{9}$$

$$\mathbf{TEAC} = \mathbf{SAC}/\mathbf{SPI} \tag{10}$$

The EVM basic parameters can be shown in Fig. 1.

According to the recent research lines, in this work an “Advanced EVM” is considered for project management which includes the objectives control to evaluate the risks and different project scenarios.

2.2 Project Driver: Objectives Accomplishment

Project management should be applied to every project where the owners of the final product wish to ensure that the expended resources are used efficiently. On major projects the application of good project management tools will aid in the selection of the right course when managers need to make financial and time allocation decisions.

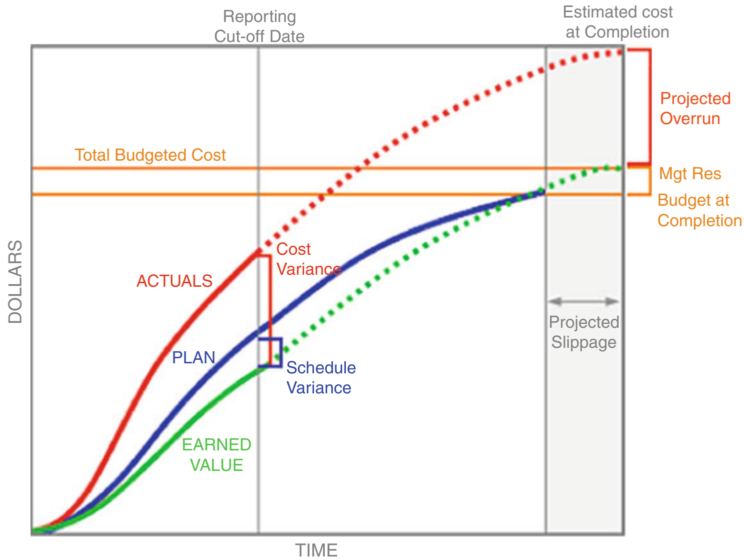

Fig. 1 EVM key parameters. Source: http://evm.nasa.gov/images/key-data.gif

According to PMBOK [1], a project is a temporary endeavor undertaken to create a product, service or result. The temporary nature of projects indicates a definite beginning and an end. The end is reached when the project's objectives are achieved or when the project is terminated because its objectives will not be met or cannot be met, or when there is no longer the need that gave rise to the project.

Business and product development are objectives oriented. One of the drivers of project control must be the accomplishment of objectives. In Fig. 2 the typical product development flow chart is presented and it can be seen that in project management for the launching of new products, it is important to highlight the fulfilling of technical objectives.

At the beginning of a project, it is usual to create a document called Statement of Work (SOW) where the tasks to be done for the achievement of the targets of the project are defined. From the SOW document on, the specifications for all the subsystems of the product or service of the project are defined.

Therefore, there is a definition of the project objectives in a top-down structure from the top management level to the task breakdown structure at the final level. And those objectives are summarized in the project documentation; this is, in the genesis of the project.

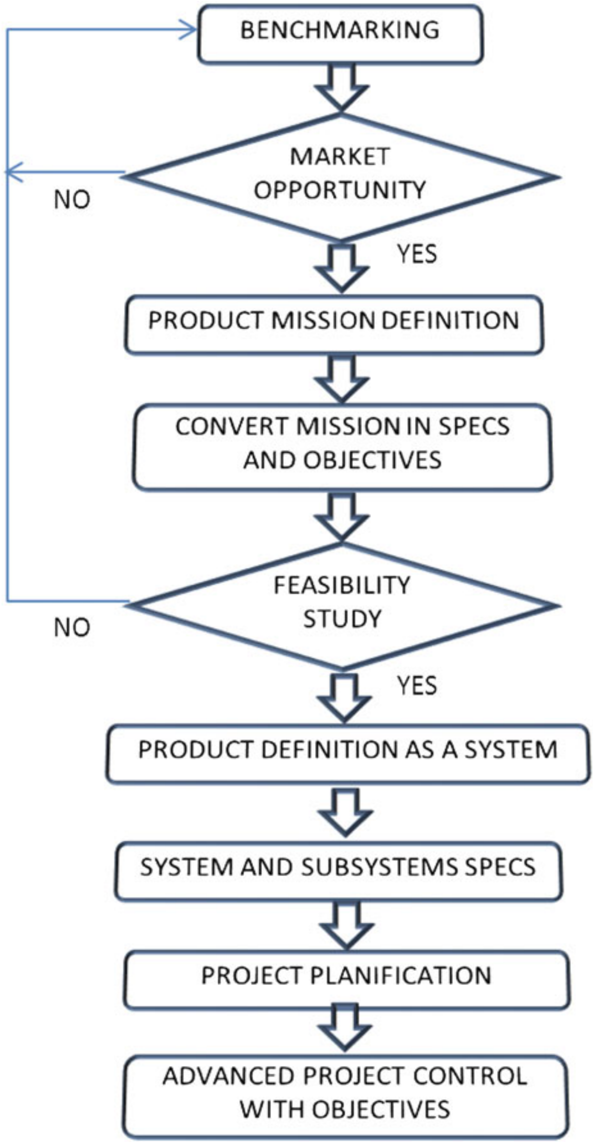

Fig. 2 Product development process oriented to objectives

3 An Analytical Model Implementing Objectives in EVM

In the projects control with EVM, more accurate analytical models are being developed including new control parameters in order to obtain more reliable information about the current and future situation of the project.

In this section, an analytical model implementing the accomplishment of the project objectives in the earned value management system is presented. It can also provide output about forecasting of objectives deviations impact at the project completion.

This formulation is a new contribution to develop the EVM especially useful for product development projects where the objectives related with product features are essential for success.

The model is based on two main concepts. The first one is the evaluation of the objectives accomplishment weighted by the objectives criticism, and the second one, the objectives deviations impact estimation at the end of the project.

3.1 Evaluation of Project Objectives Accomplishment

As it is commented in the previous section, one of the keys to decide about the project success is the objectives accomplishment.

Normally, in product development projects, objectives show different levels of criticism between them. This means that, there are objectives which are a must in the product and whose non-fulfillment implies that the product could be rejected for market launching. Mean-while, there are other objectives that are preferable and searched for but there is a bigger margin for their acceptance.

The weighting of objectives on the light of their criticism is done by the chief engineer, the product technology responsibles and/or the project managers. And this fact is usually the *BIG-BANG* of the project definition phase.

3.2 Impact of Initial Phases in the Objectives Accomplishment

Product development projects are structured following well established phases based on experience for the correct product definition. Typically these are the following ones: *conceptual design, detail design, prototypes manufacturing, testing and series launching*. These phases might differ from one project to another, be subdivided or be a part of other phases, but they commonly appear in the practice of product development projects.

In each phase, the objectives accomplishment deviation impact is different, and specifically, the impact is bigger in initial phases and it decreases as long as the last phases are reached. This means, that one deviation in the product definition at the concept phase produces a multiplier effect in the project end which is difficult to rectify.

For example, an error in the concept design phase while defining the number of engines needed to propel a commercial aircraft could lead to the project cancelation or a complete project re-thinking if it is detected in testing phase that this number of engines is not correct. On the other hand, an error in the final phase of serial launching, as a wrong dimensioning of engines production line could be corrected more easily and it implies less risk for the project.

This idea, that gives more weight to the initial phases, is captured in the model presented in this work, remarking the impact of the initial deviations in the objectives at the end of the project.

3.3 Analytical Model Description

The analytical model for implementing the project objectives in the EVM is built in for steps.

First, a weight to each project objective in function of its criticism is assigned.

Second, in each project phase, each objective accomplishment is evaluated and the weighted average of objectives accomplishment is calculated.

Third, an impact factor is assigned to each project phase in function of the effect that a deviation of the objectives in that phase has at the end of the project. Earlier the project phases bigger the impact factor. In this model the inverse of project progress is considered as the impact factor, so the impact factor can be calculated as the Budget at Completion (BAC) divided by the Planned Value (PV).

Four, the objectives weighted average powered to the inverse of project progress is applied to the EV, in order to implement both the objectives accomplishment and the initial phases impact into the EV.

The earned value implementing the objectives control and the impact of the initial phases is defined in this work as the Earned Value and Objectives (EVO).

Figure 3 shows the four steps to obtain the EVO from the project data.

Thus, the EV is minored by the objectives if they are not all fulfilled, and the model puts on the table the fact that it is not enough with the planned task completion, but also it is checked that the tasks have led to product specifications accomplishment.

The EV formulation implementing project objectives is formulated by Eq. (11).

$$\mathbf{EVO} = \left(\frac{\sum_{\mathbf{i}}^{\mathbf{n}} \mathbf{Xi} * \mathbf{Wi}}{\sum_{\mathbf{i}}^{\mathbf{n}} \mathbf{Wi}} \right)^{\mathbf{IF}} * \mathbf{EVi} \tag{11}$$

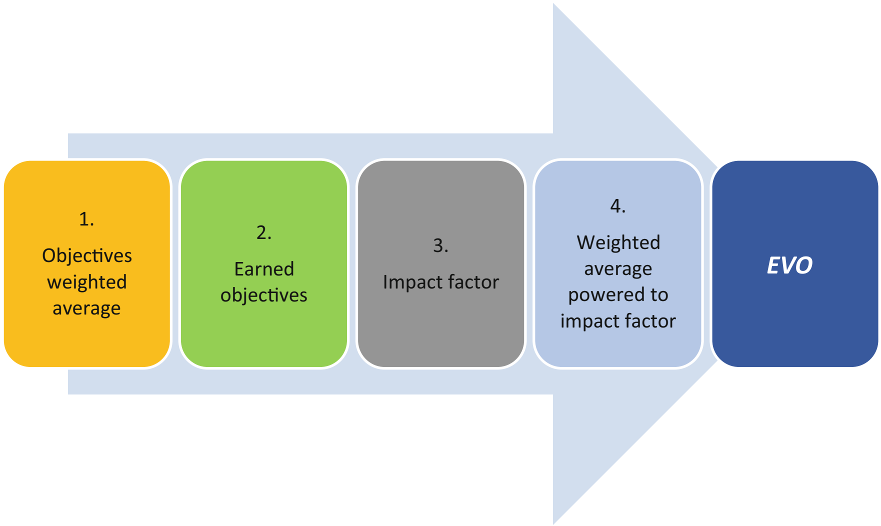

Fig. 3 Four steps for building the analytical model

Where,

EVO = Earned Value and Objectives
EV = Earned Value in each project phase
Xi = objective achievement in each project phase
Wi = objective weight
IF = phases impact factor, calculated as the inverse of project progress
IF = BAC/PVi
n = number of project phases

Besides, the model presented in this work incorporates a formulation to make a forecasting of the Earned Value and Objectives (EVO) at the project completion.

As it was commented in Sect. 2 about the EVM overview, there could be different forecasting formulas depending on the considerations made about the future project progress.

In this model, it is considered that past performance is a good predictor of future performance. Thus, the Earned Value and Objectives At Completion (EVOAC) is formulated by Eq. (12):

$$\mathbf{EVOAC} = \mathbf{EVO} + (\mathbf{BAC} - \mathbf{EVO})/\mathbf{SPIevo} \tag{12}$$

Where,

EVOAC = Earned Value and Objectives At Completion
EVO = Earned Value and Objectives
BAC = Budget At Completion
SPIevo = Schedule Performance Index with EVO. Calculated by Eq. (13).

$$\mathbf{SPIevo} = \mathbf{EVO}/\mathbf{PV} \tag{13}$$

At project completion, it is necessary to earn all the planned value; however, the EV reduction when the objectives fulfillment is implemented implies that more actions have to be taken to successfully terminate the project.

3.4 Example of Application of the Model

In this section, an example of the analytical model implementing the objectives in the EV is shown.

This example is based on the general features of a typical commercial aircraft development project. The project has five phases and seven objectives. It is considered that the project progress follows a PERT function.

The PERT function can be used to model events which are constrained to take place within an interval defined by a minimum and maximum value. For this reason, the Pert function is used extensively in PERT, Critical Path Method (CPM), Joint Cost Schedule Modeling (JCSM) and other project management/control systems [19] to describe the time to completion and the cost of a task.

The PERT function is a family of continuous functions defined on the interval [0, 1] parameterized by two positive shape parameters, denoted by α and β, that appear as exponents of the random variable and control the shape of the function.

In project management, shorthand computations are widely used to estimate the mean and standard deviation of the beta distribution like the ones collected in Eqs. (14) and (15).

$$\mu(\mathbf{x}) = \frac{\mathbf{a} + 4\mathbf{b} + \mathbf{c}}{\mathbf{c}} \tag{14}$$

$$\boldsymbol{\sigma}(\mathbf{x}) = \frac{\mathbf{c} - \mathbf{a}}{6} \tag{15}$$

where a is the minimum, c is the maximum, and b is the most likely value (the mode for $\alpha > 1$ and $\beta > 1$).

The above estimate for the mean $\mu(x)$ is known as the PERT three-point estimation and it is exact for either of the following values of β (for arbitrary α within these ranges):

– $\beta = \alpha > 1$
– $\beta = 6 - \alpha$ for $5 > \alpha > 1$

The PERT function used in the model has $\beta = \alpha = 3$, and it is shown in the following graph.

Figure 4 shows the PERT function and then the PERT cumulative function modeling the typical project progress behavior with smooth begin and end. Also, in Fig. 4, the Impact Factor function is calculated as the ratio of the Budget At

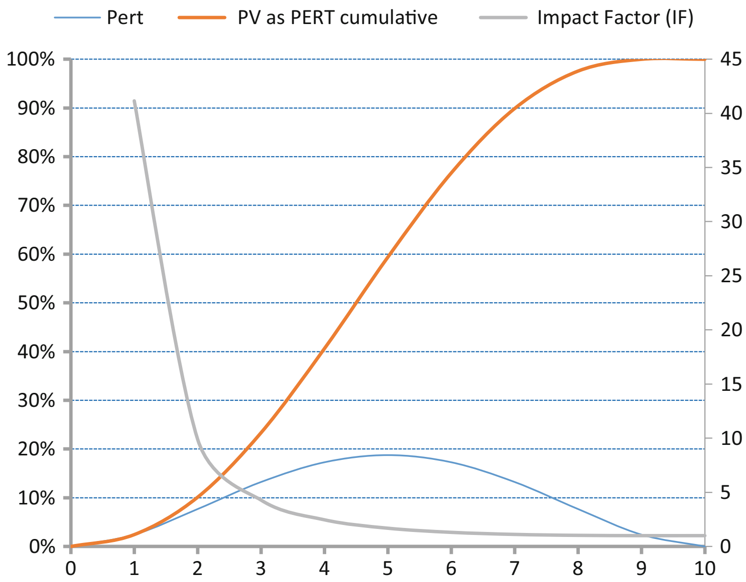

Fig. 4 PERT, PERT cumulative and impact factor functions

Table 1 Model application example

EVM parameters		
Phase	PV	EV
0	0,00	0,00
1	0,10	0,07
2	0,41	0,30
3	0,77	0,63
4	0,97	0,85
5	1,00	0,90

PV and EV values

Completion and the Planned Value, where the Planned Value is the PERT cumulative function. The first point of the Impact Factor function tends to infinite as the first point of the Planned Value tends to zero, thus, it is a singularity not considered. This fact also happens in the real projects where in the first point there is no significant planned value.

Once project data is known, it is possible to calculate the EVM parameters. The Planned Value is the project progress modeled with the PERT cumulative function. For EV calculation certain task completion in each project phase is considered. In Table 1 and Fig. 5, the PV and EV values for this example are shown.

The goal of this method is the objectives accomplishment. For this to happen monitoring of objectives is fundamental. Thus, the next step is to evaluate the accomplishment of objectives at every phase. Then, the weighted average is calculated (Table 2).

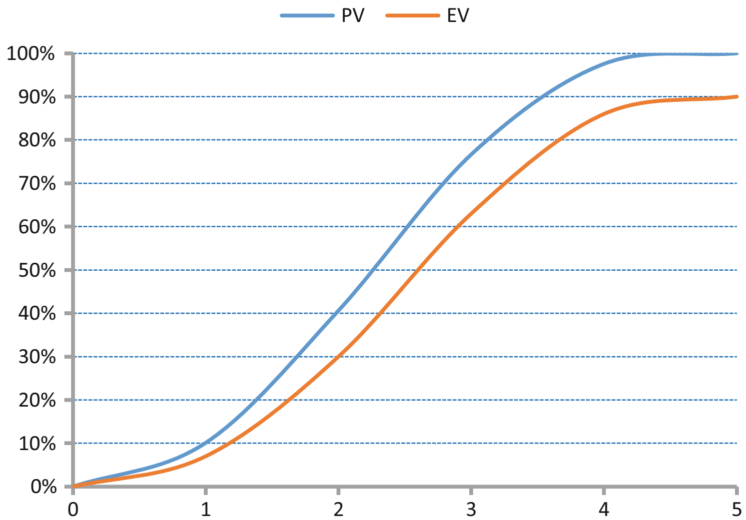

Fig. 5 Model application example. PV and EV curves

Table 2 Model application example

		Project phases					
		0	1	2	3	4	5
Objective	Weight	Earned	Earned	Earned	Earned	Earned	Earned
Thrust	0,3	0	0,95	0,90	0,90	0,85	0,85
Compresion	0,1	0	1,00	1,00	1,00	1,00	1,00
Passengers	0,05	0	1,00	1,00	0,90	0,90	0,90
Performance	0,2	0	1,00	1,00	0,90	0,95	0,97
Weigth	0,2	0	1,00	1,00	1,00	1,00	1,00
Consumption	0,05	0	0,95	0,90	0,90	0,85	0,85
Autonomy	0,1	0	0,90	0,85	0,95	0,95	0,98
Weighted average		0	0,973	0,950	0,935	0,928	0,936

Objectives weighted average

Earned Value and Objectives (EVO) is the calculated. This earned value implementing objectives takes into account not only the work finished, but also the degree of Project objectives accomplishment and the impact of the initial phases.

PV, EV and EVO values may be observed in Table 3 and Fig. 6.

Besides implementing objectives in the EVM, as previously commented, a forecasting of the impact of the deviation of the objectives at the end of the project may be done. This impact is calculated by the power of the weighted average to the inverse of project progress, i.e., the Impact Factor. This Impact Factor considers that a deviation in the initial phases has a larger effect at the end of the project than a deviation in the final phases.

Table 3 EVO calculation

PV	EV	Objectives weighted average	Impact factor	EVO
0,000	0,00	0,000	–	–
0,101	0,07	0,973	9,891	0,053
0,406	0,30	0,950	2,461	0,264
0,766	0,63	0,935	1,305	0,577
0,976	0,86	0,928	1,025	0,796
1,000	0,90	0,936	1,000	0,842

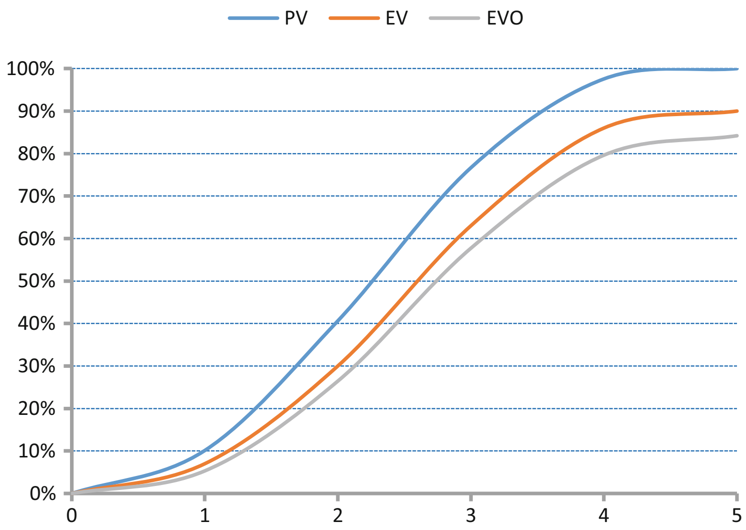

Fig. 6 EVO representation against PV and EV

Figure 7 shows EVO and EVOAC linked by lines which express the projection of the EVO at the end of the project to obtain the EVOAC.

4 Case Study

The analytical model has been applied to a real engineering product development project where the drivers are the technical objectives for the operating of a combustion engine for power generation.

Project began in January 2004 and was delayed 1 year by material procurement problems. But once new deadlines were negotiated with suppliers, it was launched again in 2005 and an overall tracking of the technical targets, cost and schedule began. In this project, the engineering consultancy delivered a design that was slightly below the technical targets of engine performance and efficiency, which was penalized in their fees. The engine efficiency target was 47 % but an engine

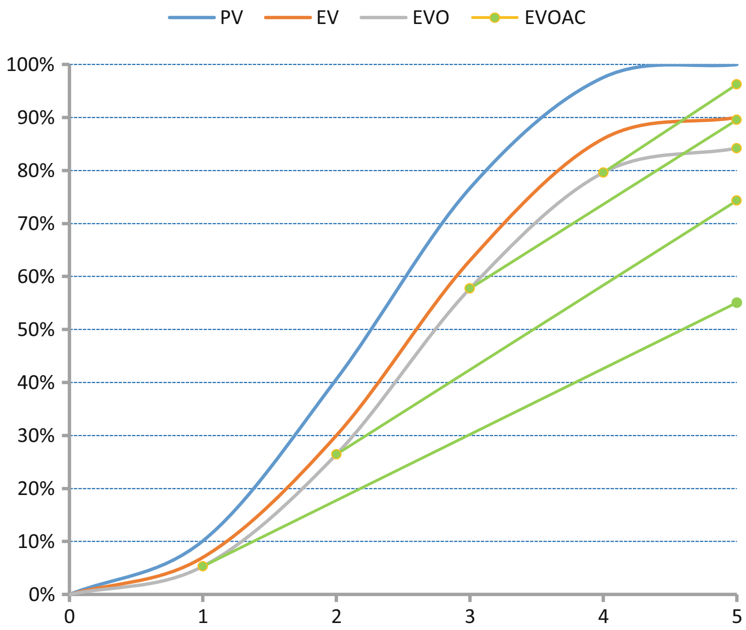

Fig. 7 EVOAC representation

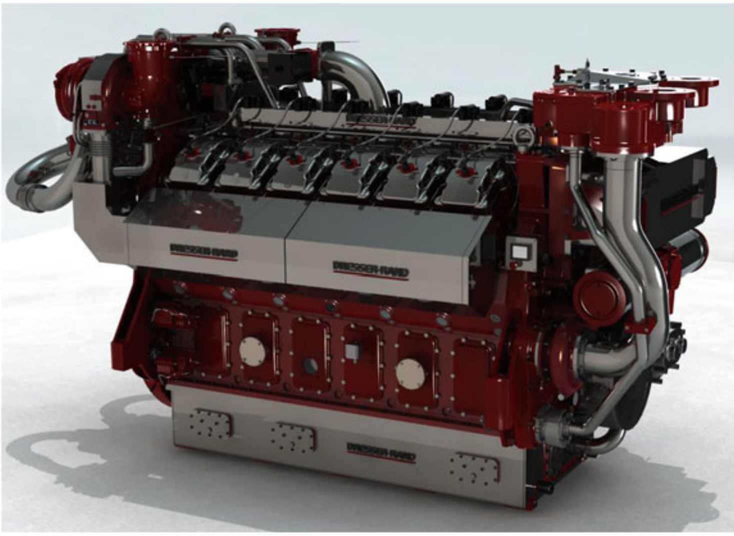

Fig. 8 V12 combustion engine. Dresser-Rand Inc. courtesy

with 45 % efficiency was obtained. Finally, the project was completed in January 2008, bringing to the market the new engine with a very good acceptance and overall rating of satisfactory (Fig. 8).

Table 4 Project objectives

Objectives	Weight	Values	Max	Min
Performance	0,3	47 %	50 %	44,5 %
Power	0,05	2.140	2.250	1.995
Pressure	0,05	15	15,75	14,25
Cost (€/kW)	0,3	120	140	100
Durability	0,2	60.000	63.000	57.000
Emissions	0,05	500	525	475
Consumption	0,05	0,2	0,21	0,19
Weighted average			1,088 %	0,913 %

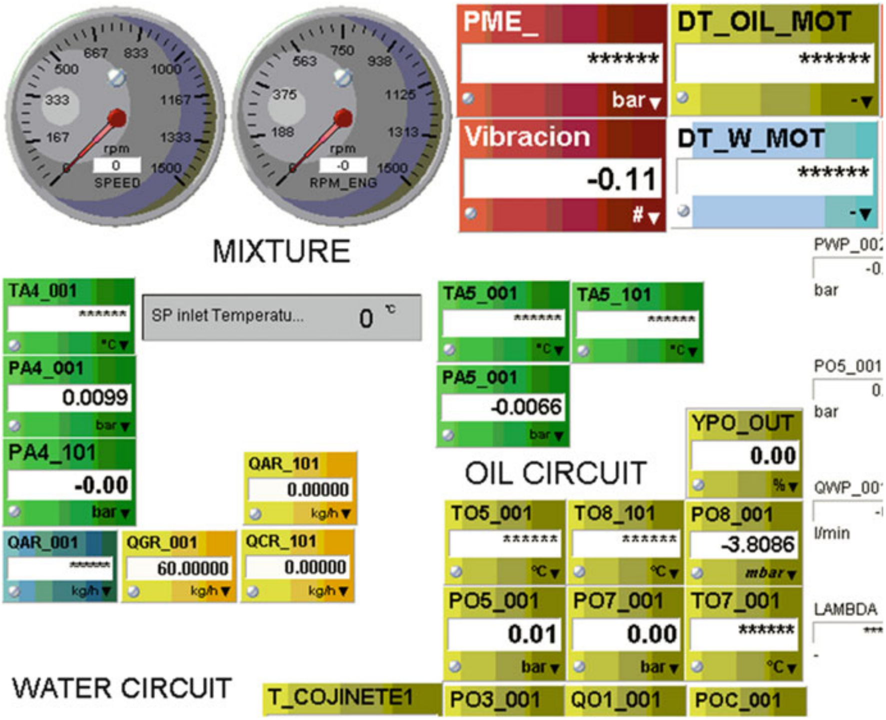

Fig. 9 Engine control unit monitoring engine performance

The project was scheduled in six phases of product development, such as, the concept design, detail design, prototypes construction, performance test, endurance test and series launching. The main objectives and their maximum and minimum acceptable values were defined in the project in order to decide the margins of acceptance for engine launching to the market. In Table 4 are presented the values for the objectives and the margins, as well as, the weighted average of the margins.

In Fig. 9, it is shown the tracking of the engine main running parameters, which were the objectives during the project.

Table 5 Project cumulative cost data

Project cumulative cost data (Thousands of Euros)							
Date	Materials	Investment	Labour	Testing	Engineering outsourcing	Trips	Total
Dec-05	178	206	55	14	425	10	889
Jan-06	148	206	74	22	678	10	1.139
Apr-06	174	219	131	50	678	10	1.263
Jul-06	248	259	172	75	679	11	1.444
Oct-06	308	260	197	93	679	12	1.549
Nov-06	316	260	208	101	679	12	1.576
Dec-06	383	262	211	104	995	12	1.967
Oct-07	417	279	309	176	1.443	13	2.637
Jun-08	444	279	401	242	1.522	16	2.905
Aug-08	445	279	425	261	1.523	16	2.950
Nov-08	472	279	475	281	1.526	23	3.056
Dec-08	473	279	488	281	1.526	23	3.070

In the analyzed project the available information for tracking along all the project life cycle was the following documents:

– The initial baseline schedule in MS Project software. It is detailed with multiple tasks levels and including the starting and finishing dates, as well as the dependences between them.
– The total budget of the project made at the beginning of the project and its breakdown in six general cost issues as follows: material costs, tooling investments, engineering hours, outsourcing expert consultancy support hours, testing costs and trips.
– A monthly report with the technical, economical and scheduling tracing. The technical part of the report includes a list of all manufacturing drawings and the testing results. The economical part of the report included cost monthly figures of the general spending issues collected from the invoices. The scheduling part of the report includes approximate deadlines for the critical tasks but not a detailed scheduling tracking.
– The general accounting of the project with the invoiced costs per month. There are available monthly figures of six general cost issues as it is shown in Table 5.

EVO method is here below applied, with real data from this project to analyze if it is possible to report status of the project in time, cost and technical compliance, to predict future project outcomes.

First of all, EVM has been applied to the data of the case study. The basic metrics for this methodology have been successfully obtained, such as AC, PV and EV, and their cumulative values which have been plotted throughout the project.

The total budget is equally distributed in the project periods to obtain the PV as used by some authors [20] (Fig. 10).

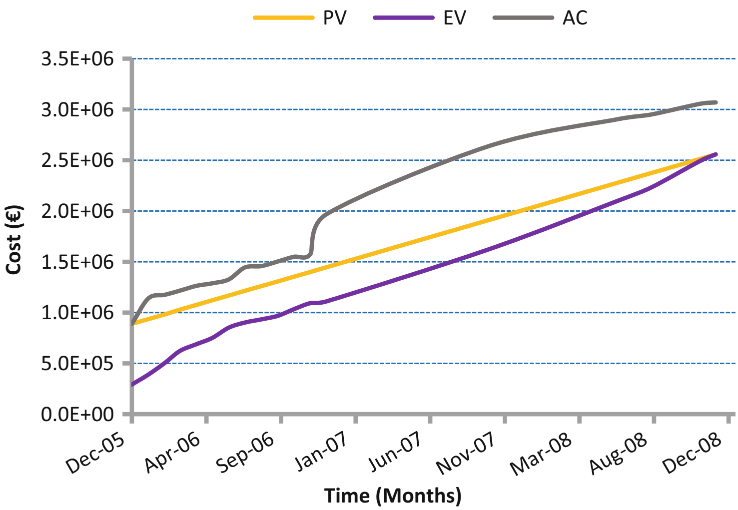

Fig. 10 EVM parameters PV, EV and AC

Table 6 Objectives accomplishment measurement and weighted average

Objective	Weight	Project phases					
		1	2	3	4	5	6
		Earned	Earned	Earned	Earned	Earned	Earned
Performance	0,3	1,00	0,96	0,90	1,00	0,85	0,87
Power	0,05	1,00	1,00	1,00	1,00	1,00	1,00
Pressure	0,05	1,00	1,00	1,00	1,00	1,00	1,00
Cost €/Kw	0,3	1,00	1,00	1,00	0,90	0,95	0,97
Durability	0,2	1,00	1,00	1,00	1,00	1,00	1,00
Emissions	0,05	1,00	0,95	0,90	0,9	0,85	0,87
Consumption	0,05	0,9	0,90	0,80	0,99	0,98	0,98
Weighted average		0,995	0,981	0,955	0,965	0,931	0,947

In parallel, it is possible to evaluate the objectives accomplishment measurement for each project phase. In this case study, the earned objectives in the first three phases are based on previous experience on five similar projects.

In Table 6 the objectives accomplishment measurement is shown, i.e., the “earned objectives”, at the different project phases. From this measurement, the earned objectives weighted average is calculated (Table 7).

The new parameter EVO compared with EV and PV is presented in Fig. 11.

In Fig. 12, EVO values are shown including the maximum and minimum for acceptance.

Figure 13 shows the EVO maximum and minimum and their projection at the end of the project, this is, EVOACmin and EVOACmax, connected by lines. The areas formed by the EVOmin-EVOACmin-EVOACmax-EVOmax establish the limits for the EVO for each point of control. In this picture the EV is also plotted in order to locate the EVO margins in the EVM system.

Table 7 EVO calculation

PV	EV	Objectives weighted average	Impact factor	EVO	EVOmax	EVOmin
981.841	504.183	0,995	2,605	497.641	628.348	397.910
1.120.934	750.057	0,981	2,282	717.093	909.583	609.603
1.260.026	932.495	0,955	2,030	849.273	1.107.005	775.425
1.399.119	1.092.581	0,965	1,828	1.022.706	1.275.116	925.359
2.280.037	2.102.206	0,931	1,120	1.941.324	2.311.257	1.898.478
2.558.222	2.558.222	0,947	1,000	2.424.554	2.783.774	2.336.052

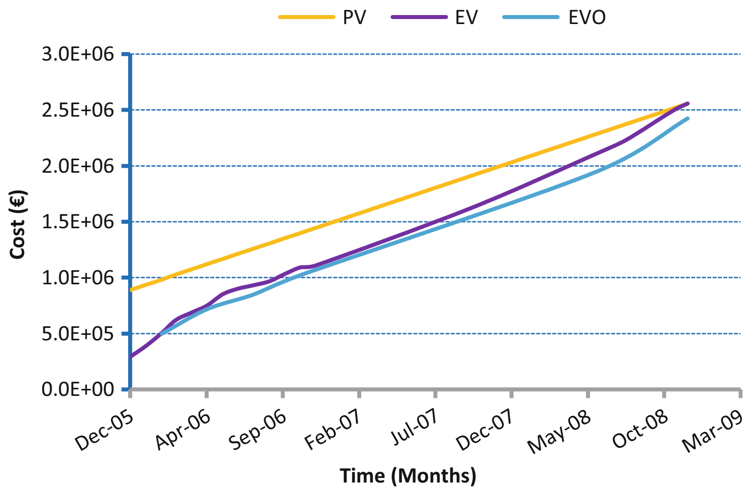

Fig. 11 PV, EV and EVO curves

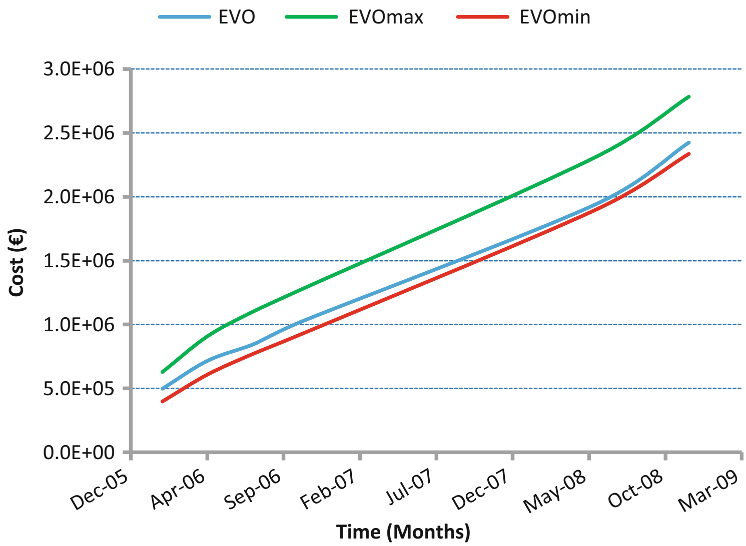

Fig. 12 EVO and its margins, EVOmax and EVOmin

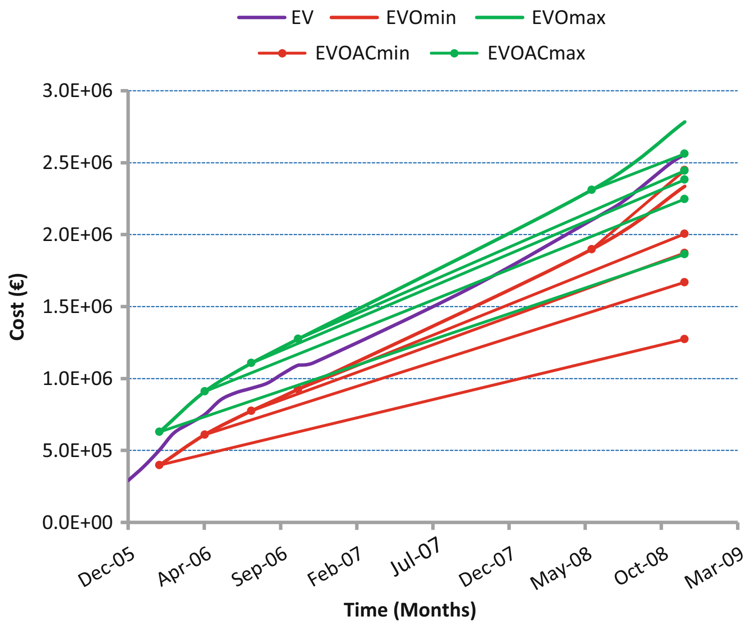

Fig. 13 EVO and EVOAC margins

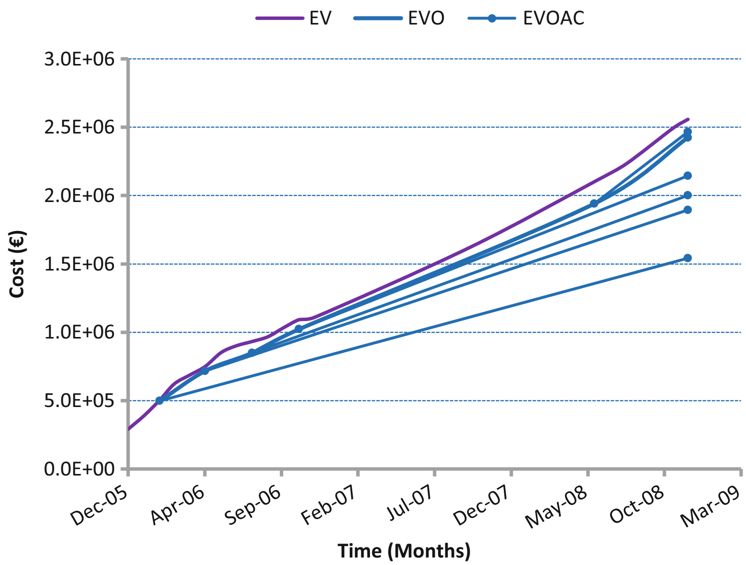

Fig. 14 EVO and EVOAC

Finally, Fig. 14 shows the EVO and the EVOAC obtained in this case study. These values must be inside the limits, and any deviation could be analyzed to take corrective actions.

5 Conclusions

Once the described model has been applied to real engineering project data, as it was in the case study, the following conclusions can be extracted:

– The evaluation of the objectives accomplishment measurement requires technical point of view, but it is possible to calculate it and their estimation at the end of the project using available project data and the formula presented in this work.
– EVO values are consistent during the complete project life. At the beginning of the project the objectives are closer to the planned ones but the impact of a deviation is bigger. This is the opposite at the end of the project.
– EVOAC demonstrates the impact of the initial phases in the objectives accomplishment at the end of the project. In this sense, EVOAC can quantify the effects of the deviations at crucial initial phases, regarding technical objectives.
– EVOAC must be between EVOACmax and EVOACmin at the end of the project, so that EVOAC measurement during the project allows correcting the product performance if needed.
– This formulation permits project managers to take decisions not only about cost and schedule but also about product definition and its embedded specifications.

References

1. PMBOK (2004) A guide to the Project Management Body of knowledge. Project Management Institute
2. Fleming Q, Koppelman J (1998) Earned value project management. J Def Softw Eng
3. American National Standards Institute (1998) Earned value management systems. ANSI/EIA-748-A-1998
4. DOD Earned Value Management Implementation Guide. U.S. Department of Defense. http://www.acq.osd.mil/evm/resources/guidance-references.shtml. Accessed 10 February 2012
5. Humphreys and Associates. http://www.humphreys-assoc.com/evms/evms-implementation-ta-a-18.html. Accessed 17 February 2012
6. National Aeronautics and Space Administration. NASA. http://evm.nasa.gov. Accessed 3 February 2012
7. Noori S, Bagherpour M, Zorriasatine F (2008) Designing a control mechanism for production planning problems by means of earned value analysis. J Appl Sci 8(18):3221–3227, ISSN 1812-5654
8. Vanchoucke M, Vandevoorde S (2008) Earned value forecast accuracy and activity critically. Measurable News Summer (3):13–16
9. Fleming Q, Koppelman J (2009) The two most useful earned value metrics: the CPI and the TCPI. J Def Softw Eng
10. Lipke W (2003) Shedule is different. The Measurable News, 31–34
11. Lipke W, Zwikael O, Henderson K, Anbari F (2009) Prediction of project outcome: the application of statistical methods to earned value management and earned schedule performance indexes. Int J Project Manag 27(4):400–407
12. Pajares J, López-Paredes A (2011) An extension of the EVM analysis for project monitoring: the Cost Control Index and the Schedule Control Index. Int J Proj Manag 29(5):615–621

13. Acebes F, Pajares J. A new approach of project management under uncertainty. Int J Proj Manag. Accepted 13 August 2013
14. Solomon P (2001) Practical software measurement, performance-based earned value. J Def Softw Eng
15. Solomon P (2005) Performance-based earned value. J Def Softw Eng
16. Solomon P (2006) Practical performance-based earned value. J Def Softw Eng
17. Solomon P (2008) Integrating systems engineering with earned value management. Meas News 4.
18. Moslemi L, Shadrokh S, Salehipour A (2011) A fuzzy approach for the earned value management. Int J Proj Manag 29(6):764–772
19. Malcolm DG, Roseboom JH, Clark CE, Fazar W (1958) Application of a technique for research and development program evaluation. Oper Res 7(5):646–669. doi:10.1287/opre.7.5.646. ISSN 0030-364X
20. Anbari F (2003) Earned value project management method and extensions. Project Manag J 34 (4):12–23
21. Project Management Institute (2005) The practice standard for earned value management. Project Management Institute
22. Kerzner H (2003) Project management. A systems approach to planning, scheduling and controlling. Wiley: New York
23. Kwak Y, Anbari F (2012) History, practices, and future of earned value management in government: perspectives from NASA. Proj Manag J 43(1):77–90
24. Fleming Q, Koppelman J (2006) Start with "Simple" Earned Value. . .on All Your Projects. Meas News
25. Xu J (2010) Project integrated management based on quality earned value. In: Proceedings of the 2nd International Conference on Information Science and Engineering, pp 432–435