Journal Paper

“An overview of earned value management in airspace industry”

Advances in Intelligent Systems and Computing

Accepted 24 August 2016

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Cite as: Rodriguez, J.C.M.; Pascual, J.L.; Molina, P.C.; Márquez, F.P.G. In An overview of earned value management in airspace industry, Proceedings of the Tenth International Conference on Management Science and Engineering Management, 2017; Springer: pp 1465-1477.

DOI: 10.1007/978-981-10-1837-4_119

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Chapter 1

An Overview of Earned Value Management in Aerospace Industry

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Abstract Earned value management (EVM) is an effective project management approach. This method is used to manage project of different sectors and has been revised to improve its schedule estimates, the Earned Schedule Management and the Earned Duration Management and to include new components as quality, the quality earned value management. This paper explores the EVM methodology and proposes a model to manage projects aerospace engineers based in a real case study. The inputs in the model are the planning and the monitoring of the case study, planned value, earned value and actual cost of aerospace projects.

Keywords Earned value management · Earned schedule management · Earned duration management · Quality earned value management · Planned value · Earned Value and actual cost · Aerospace

1.1 Earned Value Management

The Earned Value Management (EVM) is a robust and effective approach for the performance of the project management. This method integrates scope, cost and time management in a single tool. EVM needs a periodic monitoring of the project

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J. Xu et al. (eds.), *International Conference on Management Science and Engineering Management 2015*,
Advances in Intelligent Systems and Computing XXX, DOI: XXXXXXXXXXXX
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and provides early indication of rates for the project management that leads adjust project strategy to carry out the planned budget and schedule.

EVM used a cost and schedule planning as baseline and two parameters to carry out the monitoring of project: The Planned Value (PV) is the baseline, defined as the time-phased budgeted package; Actual Cost (AC) and Earned Value (EV), that are the monitoring parameters, being AC the actual cost spent on time and EV is the work that was accomplished [2]. The EV is given by Eq. 1.1.

$$EV = \%Progress \times PV \text{ total.} \quad (1.1)$$

The technique of *EV* analysis requires evaluating variance between the parameters *EV*, *AC* and *PV*. The Cost Variance (*CV*) is utilized to identify if the project is more or less the planned value.

$$CV = EV - AC. \quad (1.2)$$

When the *CV* is negative, then the project is more than the budget, and if it is positive then the project is under budget. The Schedule Variance (*SV*) is the indicator to represent how advanced the project on schedule.

$$SV = EV - PV. \quad (1.3)$$

The *SV* analysis is similar to *CV*, a positive values means that the project is ahead to the planned schedule, and when it is negative means that a project is delayed from planned schedule. The indices Cost Performance Index (*CPI*) and the Schedule Performance Index (*SPI*) are used to evaluate the efficiency.

$$CPI = EV/AC, \quad (1.4)$$

$$SPI = EV/PC. \quad (1.5)$$

CPI and *SPI* indices indicate the efficiency of the project in cost and schedule. The

Fig. 1.1 Conceptual EVM graph

main acronyms and definitions of EVM are given in Practice Standard for Earned Value Management of PMI.

The approach does a projection of the Estimate At Completion (EAC) that may differ from the Budget At Completion (BAC) was developed. It allows analyzing

PV with an estimate of cost (from AC) and schedule estimation (from EC) from the current time. This analysis results the following parameters and index:

Fig. 1.2 Budget at completion, estimate completion date, planned completion date, estimate completion date, estimate at completion and variance at completion.

- **BAC:** Budget at completion. This is the total budget baseline of project.
- **ECD:** Estimate completion date.
- **PCD:** Planned completion date.
- **EAC:** Estimate at completion.
- **Projected cost (EAC) according the initial budget:** Whether you are below or above the initial budget, the cost of the remaining work will be carried out as originally budgeted.

$$EAC = AC + (BAC - EV). \quad (1.6)$$

- **Projected cost (EAC) according to current CPI:** Regardless of the efficiency or inefficiency in resource use, costs of the remaining work will maintain the same level of efficiency or inefficiency, it is expected that the project has experienced the date continue in the future.

$$EAC = AC + (BAC - EV)/CPI. \quad (1.7)$$

- **Projected cost (EAC) according CPI and SPI:** The corresponding to the ETC work will be done according to a ratio of efficiency that takes into account both the rate of cost performance (CPI) and the index of schedule performance (SPI), schedule delays also affect costs.

$$EAC = AC + (BAC - EV)/(CPI \times SPI). \quad (1.8)$$

- **Variations of this method measures the CPI and SPI:** According to different weight values, which are in the opinion of the project manager, for example, you can take 70% of CPI and 30% of SPI.
- **Projected cost (EAC) based on new estimates:** The new estimates allow more precise estimates, but it is a much slower method. It consists add the actual cost (AC) the present value of the remaining tasks.

$$EAC = AC + (BAC - EV) / (CPI \times 0.7 + SPI \times 0.3). \quad (1.9)$$

- **ETC:** Estimate to complete

$$ETC = EAC - AC. \quad (1.10)$$

- **VAC:** Variance at completion.

$$VAC = BAC - EAC. \quad (1.11)$$

When the VAC is negative, then the project is over the planned budget, and if it is positive then the project is under planned budget.

$$VAC\% = (VAC/BAC) \times 100. \quad (1.12)$$

The original EVM has been modified to adapt the necessities of present projects. The Earned Schedule Management (ESM) is an EVM extension that tracks program schedule in units of time rather than units of budget [9–11]. The Earned Duration Management (EDM) is an EVM extension which is more effective to manage the schedule than EVM and ESM [7]. The Quality Earned Value Management (QEVm) includes the quality component [6].

1.2 The Earned Schedule Management

ESM is more effective to evaluate the program schedule performance than the EVM. Earned Schedule (ES) identifies the time at which the amount of EV accumulated should have been earned. ES uses time-based indicators and performance indicators, and also metrics to provide schedule variance and performance efficiency management information in order to analyze the program progress against the budgeted plan. ES provides schedule performance results to support the program manager in the successful completion of a program [9–11].

In ESM, the performance indicators EV and Planned Value ($PV = EV$ when a program nears completion) are used to calculate ES, that is given by Eq. (1.13).

$$ES = t + (EV_{t+2} - PV_t) / (PV_{t+1} - PV_t). \quad (1.13)$$

This equation uses the current EV and PV data values that are supplied in monthly CPRs.

The Schedule Performance Index, $SPI(t)$, is the important performance metrics derived from the ES . $SPI(t)$ shows the efficiency of a program in the performance of the schedule. This index is calculated with Actual Time (AT) and ES :

$$SPI(t) = ES/AT. \quad (1.14)$$

ES incorporates time with the Planned Duration (PD) and $SPI(t)$ values over the time (t) to calculate the final duration forecast. $IEAC(t)$ is given by Eq. (1.15).

$$IEAC(t)_{ES} = PD/SPI(t). \quad (1.15)$$

The ES metrics lead EVM to use duration forecast methods in all of the project life cycle (early stage, mid stage and late stage).

1.3 The Earned Duration Management

The Earned Duration Management (EDM) is an EVM extension which uses cost and schedule indicators to monitor and analyze the project progress. The EDM was created to improve the shortcomings of ES for assessing the schedule performance of projects. The usage of time-based data for the generation of progress indicators is the basic concept of this method [7]. The EDM methodology uses the Total Planned

Fig. 1.3 Total planned duration and total earned duration

Duration (TPD), which replaces PV and the Total Earned Duration (TED), which replaces EV:

$$ED = t + (TED_{t+2} - TPD_t) / (TPD_{t+1} - TPD_t). \quad (1.16)$$

The ED schedule performance measures are shown in Table 1.5, together with those based on EVM/ES . There is a similarity between the equations for both sets of indicators.

The Duration Performance Index, $SPI(t)$, is a representation of how efficiently a program is performing to schedule. This index is calculated with Actual Duration (AD) and ED:

$$SPI(t) = ED/AD. \quad (1.17)$$

1.4 The Quality Earned Value Management

The Quality Earned Value Management (QEV) is an EVM extension to include the quality component in this method. The QEV aim is to show the project efficiency to deliver the project quality requirements based on the used time and spent money [6]. The main QEV components are the Quality Requirements (QR), Qual-

Fig. 1.4 Planned value, actual cost, earned value and quality earned value

ity Variance (QV), Quality Performance Index (QPI), Quality Index Number (QIN), and Quality Earned Value (QEV). Dodson [6] presented the third element of earned value management, where the main components are summarized in Table 1.1.

1.5 EVM in Aerospace Industry

Swedish Industry Group JAS (IG JAS) use EVM for the Gripen project (Saab JAS 39 Gripen, light single-engine multirole fighter aircraft manufactured). The Swedish Government was who decided the implementation of the EVM system for this project in 1982 [3].

The EVM was applied by the National Aeronautics and Space Administration (NASA) to obtain a more efficient projects management, mainly for the project with budget constraints. An example of this was the STARDUST mission project. STARDUST was the Discovery Program's fourth mission [4]. With EVM and other management tools, the project and mission managers, Lockheed Martin Astronautics (LMA) and Jet Propulsion Laboratory (JPL), managed to complete on time with nearly \$2M under budget. The project managers implanted efficiently the EVM and accomplish a reduction in time of evaluation of earned-value of a month to a week, allowing them to react quickly against deviations from the plan.

In 2004, Exploration Systems Mission Directorate of the NASA (ESMD) decided to implement a highly specific monthly EVM report in relatively small projects (budget from 1 to 10 million dollars) [12]. This implementation was not easy by the difficulty highly specialized language and the absence of adequate tool. ESMD used the NASA Program Management Tool (PMT) to implement a full set of EVM reporting capabilities. This tool was used by project managers for project planning and reporting and the data input templates was modified to generate the EVM re-

porting. This new tool (PMT EVM module) reduced the time to collect the cost and schedule data to one or two days, the project managers had more time for variance analysis and creating actions.

Department of Defense (DoD) is other US department which uses EVM as a management tool. The US Air Force F-22 fighter program is an example [5]. This

Table 1.1 Description of QEVm components [6]

Name	Description	Formula
Quality Requirements (QR)	It is the quality requirements for a given task. The unit may vary according to the QR.	
Quality Performance Index (QPI)	Indicates how efficient the project is conducted to meet the task's QR. It is used when a task has one quality requirement or as part of the Quality Index Number (QIN) when a task has more than one QR.	$QPI = \begin{cases} 1, & \text{when the quality requirements are met} \\ 0, & \text{when the quality requirements are NOT met} \end{cases}$
Quality Earned Value (QEV)	The earned value of the work that met QR of the performed work. It is estimated by multiplying the QPI (or QIN) by the Actual Costs (AC) expressed in monetary units.	$QEV = QPI \times AC$
Quality Variance (QV)	Indicates the cumulative quality efficiency of the project.	$QV = QEV/CAC$

project management methodology is used by big aerospace companies as Airbus and Boeing. The Boeing Company published in 1999 a manual Integrated Performance Management Practice, which had as scope to be used to implement EVM in all Boeing organizations. Boeing also collaborated with the National Defense Industrial Association to write the industry EVMS standard [1]. Bombardier also used EVM concepts for projects management [8].

1.6 The Model

1.6.1 Real Case Study

The planning values are given in Table 1.2. The current values are given in Table 1.3. Table 1.4 shows the earned values.

1.6.2 Calculations and Results for the Decision Making

The model uses to evaluate cost and schedule date the parameters previously presented:

Table 1.2 Planned value

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC
R1	0	0	0	0	0	0	0	0	0	0	0	0
R2	175	369	544	728	903	1097	1263	1351	1534	1738	1942	2078
R3	0	0	0	0	0	0	0	0	0	0	0	0
R4	50	107	157	210	261	317	365	390	443	502	561	600
R5	26	56	82	110	137	166	192	205	233	263	294	315
R6	885	1868	2753	3688	4573	5556	6397	6843	7769	8801	9834	10522
R7	1620	3420	5040	6750	8370	10170	11710	12525	14220	16110	18000	19260
R8	0	0	0	0	0	0	0	0	0	0	0	0
R9	42	89	131	175	217	264	304	325	369	418	467	500
R10	42	89	131	175	217	264	304	325	369	418	467	500
R11	0	0	0	0	0	0	0	0	0	0	0	0
R12	385	770	1155	1540	1925	2310	2695	2870	3080	3255	3430	3500
R13	0	0	0	0	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0	0	0	0	0
R15	252	533	785	1051	1304	1584	1824	1951	2215	2509	2804	3000
R16	21	44	65	88	109	132	152	163	185	209	234	250
R17	0	0	0	0	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0	0	0	0	0
R20	21	44	65	88	109	132	152	163	185	209	234	250
R21	13	27	39	53	65	79	91	98	111	125	140	150
R22	0	0	0	0	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0	0	0	0	0
Rt	3533	6	1099	14656	18189	22072	25448	27208	30711	34559	38407	40925

Fig. 1.5 Case study: planned value, actual cost and earned value

Table 1.3 Current value

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU
R1	0	0	0	0	0	0	0	0
R2	297	642	881	1024	1113	1130	1176	1185
R3	0	0	0	0	0	0	0	0
R4	65	142	199	300	401	437	510	523
R5	15	15	15	93	120	148	190	199
R6	1110	2295	3217	4381	5073	6021	6800	7064
R7	1966	3707	5474	8852	11185	12735	15057	15615
R8	0	0	0	0	0	0	0	0
R9	0	0	0	47	47	47	146	148
R10	172	240	296	332	414	485	555	601
R11	0	0	0	0	0	0	0	0
R12	449	1066	1689	2476	3251	4128	5116	5196
R13	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0
R15	138	298	361	388	501	618	762	811
R16	20	39	68	83	89	98	128	128
R17	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0
R20	0	0	0	0	0	0	0	0
R21	84	86	89	89	89	137	137	137
R22	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0
Rt	4316	8530	12289	18064	22282	25982	30575	31607

$$CV = EVCAC, \quad (1.18)$$

$$SV = EVCPV, \quad (1.19)$$

$$CPI = EV/AC, \quad (1.20)$$

$$SPI = EV/PC, \quad (1.21)$$

$$CV\% = (CV/EV) \times 100, \quad (1.22)$$

$$SV\% = (SV/PV) \times 100, \quad (1.23)$$

$$EAC = AC + (BAC - EV)/(CPI \times SPI), \quad (1.24)$$

$$ETC = EAC - AC, \quad (1.25)$$

$$VAC = BAC - EAC, \quad (1.26)$$

$$(1.27)$$

Tables 1.5, 1.6 and 1.7 show the resulted of evaluation of project progress, the cost and schedule conclusions and the estimating project completion.

Acknowledgements This paper analyzed an earned value management approach to airspace engineering projects. The main characteristic of the model is the unit used to measure the cost, hours. Using hours as cost unit, the estimate at completion may be used as estimate completion date. Therefore the model provides the time required to complete the project with a cost estimation.

Table 1.4 Earned value

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU
R1	0	0	0	0	0	0	0	0
R2	292	630	866	1005	1113	1639	1706	1719
R3	0	0	0	0	0	0	0	0
R4	64	140	196	295	393	429	501	513
R5	15	15	15	91	118	145	186	195
R6	1090	2253	3159	4301	4981	5912	6676	7064
R7	1930	3640	5374	8691	10981	12503	14783	15615
R8	0	0	0	0	0	0	0	0
R9	0	0	0	46	46	46	144	146
R10	170	236	292	327	407	477	546	581
R11	0	0	0	0	0	0	0	0
R12	441	1047	1658	2432	3034	3853	4532	4209
R13	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0
R15	135	292	354	381	491	606	748	796
R16	19	38	66	81	87	96	126	126
R17	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0
R20	0	0	0	0	0	0	0	0
R21	83	85	88	88	88	117	117	117
R22	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0
Rt	4238	8376	12067	17738	21741	25823	30064	31082

Table 1.5 Cost parameters (August 2015)

	CV	CPI	CV%	
R2	534.62	1.45	31%	Under budget
R4	−9.33	0.98	−2%	Over budget
R5	−3.73	0.98	−2%	Over budget
R6	0	1	0%	In budget
R7	0	1	0%	In budget
R9	−2.66	0.98	−2%	Over budget
R10	−19.13	0.97	−3%	Over budget
R12	−987.22	0.81	−23%	Over budget
R15	−15.27	0.98	−2%	Over budget
R16	−2.34	0.98	−2%	Over budget
R21	−20.33	0.85	−17%	Over budget
Rt	−525.40	0.98	−2%	Over budget

Table 1.6 Schedule parameters (August 2015)

	SV	SPI	SV%	
R2	367.75	1.27	27%	Ahead planned
R4	123.28	1.32	32%	Delayed from planned
R5	−9.38	0.95	−5%	Ahead planned
R6	221	1.03	3%	Ahead planned
R7	3090	1.25	25%	Delayed from planned
R9	−179.42	0.45	−55%	Ahead planned
R10	256.21	1.79	79%	Ahead planned
R12	1338.68	1.47	47%	Delayed from planned
R15	−1154.84	0.41	−59%	Delayed from planned
R16	−36.72	0.77	−9%	Ahead planned
R21	18.97	1.19	19%	Ahead planned
Rt	3873.51	1.14	14%	Delayed from planned

Table 1.7 Resulted (August 2015)

	BAC	EAC	ETC	VAC	
R2	2078	1379	28	699	Under planned budget
R4	600	590	200	10	Under planned budget
R5	315	327	122	−12	Over planned budget
R6	10522	10414	3571	108	Under planned budget
R7	19260	18539	6014	721	Under planned budget
R9	500	953	628	−453	Over planned budget
R10	500	553	228	−53	Over planned budget
R12	3500	4599	1729	−1099	Over planned budget
R15	3000	6316	4365	−3316	Over planned budget
R16	250	292	129	−42	Over planned budget
R21	150	170	72	−20	Over planned budget
Rt	40925	40369	13161	556	Over planned budget

And the cost (in hours) converts in monetary unit applying the price of the hour. The different resources ($R1, R2, \dots$) have different prices, these resources are department grouped by skills and competences.

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