Tracking Project Progress with Earned Value Management Metrics
A Real Case

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Abstract: According to the Project Management Institute (PMI) project management consists of planning, organizing, motivating and controlling resources such as time and cost in order to produce products with acceptable quality levels. As so, project managers must monitor and control project execution, i.e. verify actual progress and performance of a project with respect to the project plan and timely identify where changes must be made on both process and product. Earned Value Management (EVM) is a valuable technique for determining and monitoring the progress of a project as it indicates performance variances based on measures related to work progress, schedule and cost information. This technique requires that a set of metrics be systematically collected throughout the entire project. A consequence is that, for large and long projects, managers may encounter difficulties in interpreting all the information collected and using it for decision-making. To assist managers in this tedious task, in this paper we classify the EVM metrics distinguishing them into five conceptual classes and present an interpretation model that managers can adopt as checklist for monitoring EVM values and tracking the project's progress. At this point of our research the decision model has been applied during an industrial project to monitor project progress and guide project manager decisions.

1 INTRODUCTION

Project management is the discipline of planning, organizing, motivating, and controlling resources in order to fulfil specific goals, whereas a project is a temporary effort with a defined start and end point, usually time and budget constrained, carried out to meet unique goals and objectives and deliver results that provide added value and innovations to current practices on time and within budget (Pyster and Thayer 2005, PMI 2013) conforming to certain quality expectations.

The phases of the project management lifecycle include: project initiation, planning, execution, monitoring and control and closing (Figure 1) (PMI 2013). In planning project managers define project plans. While in monitoring and controlling they track and regulate the progress and performance of a project and identify project parts where changes must be applied. Successful project completion requires that managers continuously monitor and control the execution and progress of the activities with respect to the plan and adopt corrective actions whenever necessary. Under such conditions it is crucial that project performances be observed and measured regularly to identify variances from the project plan, comparing for example differences between actual values (budget, resource consumption, start finish dates) and planned ones. This is especially true in software contexts where, being human-centred it is difficult to predict factors such as productivity and performances, and therefore project duration and costs. Literature provides several evidences of software project failure (Marshal 2006, Pressman 2002, Standish Group 2010).

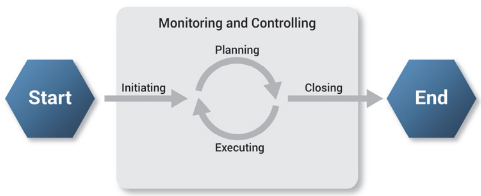

Figure 1: Project Management Lifecycle Processes (PMI 2013).

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Earned Value Management - EVM (PMI 2013) is considered among the most reliable for objectively tracking performance and progress of a project. According to Efe and Demirors (2013) EVM is defined as "Management with lights on". Traces of this technique date back to the 1800s before being adopted in military domains such as NASA (2010) and DoD (DoD 1998, DoD 2002, EVM 2000, PMI 2013) There are also several evidences of the success of this technique for project monitoring and control (Jaafari 1996, Raby 2000, Wells and Duffey 2003, Fleming and Koppelman 1998, Australia 2006, Sulaiaman 2006). There is little support in literature on decision support tools that guide data collection and interpretation as pointed out in other studies as well (Nkasu and Leung 1997, Basili et al. 2002, Garcia et al. 2004, Donzelli 2006).

Given this gap, our intention in this paper is to clarify the meaning of EVM indicators and provide guidance for their interpretation. Our contribution is therefore twofold:

- Conceptual Categories: we have organized the EVM indicators in conceptual categories each with a specific meaning and scope;
- Decision Model: we have provided a decision model able to guide project managers in interpreting EVM metric values and support them in making the most appropriate decisions during project execution.

The proposed solutions have been validated in a real industrial case study. Within the study, the conceptual classes and decision model have been used to apply the EVM metrics and interpret their values during monitoring and control activities of the entire project, in order to support decision making.

The rest of the paper is organized as follows: in the next section we describe the conceptual classes used to classify the EVM metrics, as well as the decision model we propose for interpreting EVM values. In section 3 we have presented how the model has been used in a real industrial case study where managers adopted the model for monitoring project performances. Finally conclusions are drawn.

2 PROPOSAL: CONCEPTUAL CATEGORIES AND DECISION MODEL FOR EVM METRICS

Managing a project, independently from its application domain, involves going through three phases (Figure 2): (i) define work; (ii) schedule & budget; (iii) measure performance. In "define work", project activities are identified and a work breakdown structure (or similar) is developed in order to identify the relations between the activities and work products. This structure should be detailed so the work can be categorized into individual elements of work. Next, in the "schedule and budget" phase, the project manager defines how the WBS activities are organized; Scheduling also involves arranging work packages into logical frameworks that define the project milestones. As the project progresses "monitoring and controlling" processes are carried out to measure performances.

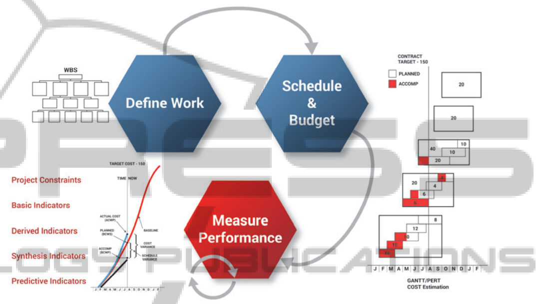

Figure 2: Project phases.

Literature offers several techniques such as COCOMO II (Bohem 2000), Use Case Points (Smith 2000) and Function Points (IFPUG 2004) that use past project data to estimate size, effort and cost. They do not allow to "monitor and control" projects. Opposed to these are approaches such as: GQM-QIP (Basili et al. 2002), PDCA (Tague 2004), TQM (Mathews 2006), and EVM (PMI 2003). The idea behind EVM is that it prevents rather than cures by identifying and solving problems early, as soon as they arise. It acts as an early alarm for signalling trends and deviations from the original project plan, so that a manager can promptly take action, make corrections and get the project back on track, in line with schedule and budget restrictions. It is important that the technique be systematically applied throughout the project in order to detect variances when they are small and easy to correct, instead of discovering unpleasant surprises at the end of the project, when the situation is unrecoverable and the project is bound to fail or be cancelled. EVM is made up of several metrics that may generate confusion for a project manager having to collect, measure, analyse and interpret them during the project lifecycle. To this end, we have proposed a classification of the metrics and organized them in conceptual categories.

2.1 EVM Conceptual Categories

The categories identified reflect the general meaning of the metrics and their application with respect to project progress. The classification consists of five categories:

2.1.1 Project Constraints

When defining the project plan the project manager must take into account the project constraints such as budget available, resources that can be assigned to the project activities, and time restrictions. In this sense, two relevant indicators that represent this information are: (i) Budget At Completion (BAC), expresses an initial estimation of budget allocated to the project; (ii) Time At Completion (TAC), expresses the initial estimation of time required to complete all the project activities. Both these indicators (Figure 3) are fixed and established when the project plan is defined.

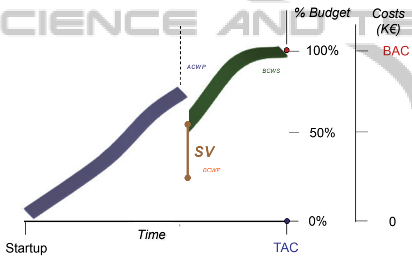

Figure 3: EVM metrics.

2.1.2 Basic Indicators

This category is made up of three metrics that express the earned value of the project at a certain point in time, generally in correspondence to a milestone established in the project plan: (i) Budgeted Cost of Work Scheduled (BCWS): planned value, is the amount of money budgeted to complete the scheduled work; (ii) Budgeted Cost of Work Performed (BCWP): earned value, is the budgeted cost of work that has actually been performed in carrying out a scheduled task at a certain time point, usually related to a milestone; (iii) Actual Cost of Work Performed (ACWP): the actual cost sustained for carrying out the project up to a specific milestone.

2.1.3 Derived Indicators

This category comprises two metrics obtained from the basic ones that express variances between planned and actual values collected in the milestone check points, in absolute values: (i) Cost Variance (CV = BCWP-ACWP): expresses the difference between the cost of the work performed in accordance to the project plan carried out up to a specific point in time (BCWP) and the actual cost sustained; (ii) Schedule Variance (SV=BCWP-BCWS): expresses the difference between the cost of the work carried out up to a certain point in time and the cost of work that should have been done according to the project plan (BCWS).

2.1.4 Synthesis Indicators

These metrics express synthetic information in percentages. Cost Performance Index (CPI) and Schedule Performance Index (SPI) are indicators of how closely accomplished work is on budget and schedule: (i) Cost Performance Indicator (CPI = BCWP/ACWP) shows the efficiency of the utilization of the resources on the project. (ii) Schedule Performance Indicator (SPI = BCWP/BCWS) shows how the work is progressing compared to the original schedule.

Both of these formulas begin with the Earned Value (BCWP), which is the value of the work already accomplished. SPI and CPI ratios help managers evaluate the project at any point and make changes.

A manager should first calculate these two synthesis indicators to have an idea of the project status and whether there is a deviation (positive or negative) from the baseline and then go into detail by considering the derived indicators (SV and CV), which provide a quantitative (absolute value) evaluation of the deviation.

2.1.5 Predictive Indicators

This category includes two metrics that express the estimate at completion (EAC) which forecasts the value of the project with respect to time and cost when the project is complete. Studies show that EACs based on CPI and SPI values tend to be significantly higher and are also more accurate (Christensen and Thayer 2001). We have adopted the following formulas for calculating them: (i) Estimate At Completion – Cost (EACC = BAC/CPI): expresses the amount of money estimated to be spent at the end of the project given its progress; (ii) Estimate At Completion – Time (EACT = TAC/SPI): estimates the end time of the project given the current state of progress.

Keep in mind that although BAC and TAC are fixed at the beginning of the project, the EAC values most likely change compatibly and conformingly as the synthesis indicators change during project execution.

2.2 Decision Model

The concept of granularity is very important in the application of EVM and interpretation of the collected values. In particular, SPI, CPI, SV and CV measured at a project level (high granularity) are useful for top management, portfolio/program managers, but turn out to be almost insignificant for a project manager who, without any other information, is not able to make any considerations or valuable interpretations. On the other hand, if the indicators are calculated with respect to an individual sub-project, phase, task (low granularity), rather than the overall project, it is possible to: monitor the actual state of the sub-project, phase, task compared to the project plan; designate budget/resources saved on an activity to mitigate risks related to other late or over budget activities, allowing to optimize project performances. The level of granularity as well as milestone checkpoints, with respect to which entity and how often EVM indicators are to be collected, should be defined at project start, taking into account the critical points and risk factors and can be changed during execution, if the case.

The resulting amount of data collected at each milestone checkpoint during the entire project is considerable. As so, its interpretation can become quite challenging for a project manager and for the entire management team involved in analysing the data, identifying weaknesses, avoiding problems from occurring and promptly acting when they arise. For this reason, as practical support to the EVM technique we have provided a decision model (Figure 4) to use at each milestone checkpoint. The model basically guides monitoring activities step by step as collected values are reported in the form and compared to baseline values. Secondly, interpretation guidance is provided in order to optimize project management by using/re-allocating available resources at their best, verifying critical points and mitigating delays or over budget risks.

Those who are responsible of managing work use this data in order to understand cost and schedule performances throughout the project lifecycle. The main goal is to point out (cost and schedule) issues early providing the maximum time to minimize their impact and provide an effective manner for developing recovery plans and improvement actions where necessary.

CHECKLIST MILESTONE N.X

Date dd/mm/yyyy

Name of monitor: Signature:____________________

Indicator to collect	Baseline Value	Collected Value
1. What is the expected cost of the work carried out (BCWP) up to this moment?	BCWP=BCWS	
2. What is the cost for the work carried out up to this moment (ACWP)?	ACWP=BCWP	
3. What is the variance between planned costs and actual costs (CV=BCWP – ACWP)?	CV>=0	
4. What is the variance between the actual and planned state of work (SV=BCWP – BCWS)?	SV>=0	
5. What are the performances in terms of execution costs for the task being considered (CPI=BCWP/ACWP)?	CPI>=1	
6. What are the performances in terms of execution times of the task being considered (SPI=BCWP/BCWP)?	SPI>=1	
7. What is the overall duration estimated for executing the task considered (EACT)?	EACT<=TAC	
8. What is the estimated overal cost for executing the task considered (EACC)?	EACC<=BAC	

INTERPRETATIONS

- If the task is under budget (CPI>1) and late in execution (SPI<1), it is necessary to involve more resources using the available budget not spent yet (CV).
- If the task is under budget (CPI>1) and early in execution (SPI>1) designate part of the budget not spent (CV) and the resources assigned to this task to make up for the delays in the execution of other project tasks.
- If the task is over budget (CPI<1) and early in execution (SPI>1) it is the case to reduce the resources assigned to the task in order to gain the extra budget spent (CV) compared to the planned.
- If the task is over budget (CPI<1) and late in execution (SPI<1) verify if it is possible to recover extra resources assigned to other tasks that are currently on time or early compared to the plan, in order to recuperate the extra budget spent (CV) until this moment compared to the project plan.
- If the project satisfies times (SPI=1) and cost (CPI=1) there are no initiatives to undertake. The project execution is compliant to its plan.

To this date, the estimated duration of the project is:	EACT=TAC/SPI=______________
To this date, the estimated overall cost of the project is:	EACC=BAC/SPI=______________

Figure 4: Decision Model for interpreting EVM metrics.

3 APPLICATION TO A REAL CASE

The conceptual categories classification and decision model have been applied in an industrial case study within a nationally funded project (here called E-MARK for convenience) that involved a University and a large IT company. The project focused on designing and developing a solution able to automate marketing processes through use of technologies that make use of traceable information on the Internet. Project monitoring and control was carried out with EVM metrics. Project managers used the proposed classification of conceptual classes as reference to systematically collect and organize the values during project execution. Furthermore, they adopted the decision model illustrated in the previous section to guide interpretation of collected values. Throughout the next paragraphs detail of the project monitoring progress is provided.

The project was organized in four work packages and nine activities. The granularity selected for applying the indicators related to each activity at fixed milestones.

In Figure 5 the planned effort and costs with respect to each project activity are reported. They are compared to the actual values collected during the project. Furthermore, Figure 6 shows the values of EVM indicators for every activity. In the following we report the results of the interpretations carried out, after applying the decision model to the EVM indicators collected.

WP	ACTIVITIES	PLANNED PERSON/DAYS	PLANNED COST	PLANNED SOLAR DAYS	ACTUAL PERSON/DAYS	ACTUAL COST	ACTUAL SOLAR DAYS
	A1	48	€ 8.151,60	18	40,07	€ 8.005,36	18
	A2	9,6	€ 1.630,32	3,6	8,01	€ 1.601,07	3,6
WP1	A3	81,6	€ 13.857,72	30,6	60,1	€ 12.008,04	27
	A4	14,4	€ 2.445,48	5,4	12,02	€ 2.401,61	5,4
WP2	A5	48	€ 8.151,60	18	20,03	€ 4.002,68	9
	A6	91,2	€ 15.488,04	34,2	76,13	€ 15.210,18	34,2
WP3	A6				16,03	€ 3.202,14	7,2
	A7	144	€ 24.454,80	54	120,20625	€ 24.016,08	54
	A7				12,02	€ 2.401,61	5,4
	A8	33,6	€ 5.706,12	12,6	28,05	€ 5.603,75	12,6
	A8				4,01	€ 800,54	1,8
WP4	A9	9,6	€ 1.630,32	3,6	4,01	€ 800,54	1,8
		480	€ 81.516,00	180	400,68	€ 80.053,60	180

Figure 5: descriptive statistics of planned and actual values.

		EVM INDICATOR VALUES								
ACTIVITY	% of progress	BCWP	BCWS	SV	ACWP	CV	SPI	CPI	EACC	EACT
A1	10%	8.151,60	8.151,60	0,00	8.005,36	146,24	1,00	1,02	80.053,60	6,00
A2	12%	9.781,92	9.781,92	0,00	9.606,43	175,49	1,00	1,02	80.053,58	6,00
A3	27%	23.639,64	22.009,32	1.630,32	21.614,47	2.025,17	1,07	1,09	74.532,66	5,59
A4	30%	26.085,12	24.454,80	1.630,32	24.016,08	2.069,04	1,07	1,09	75.050,25	5,63
A5	35%	34.236,72	28.530,60	5.706,12	28.018,76	6.217,96	1,20	1,22	66.711,33	5,00
A6	54%	41.980,74	44.018,64	-2.037,90	43.228,94	-1.248,20	0,95	0,97	83.939,70	6,29
A6	58%	49.724,76	47.279,28	2.445,48	46.431,09	3.293,67	1,05	1,07	76.116,54	5,70
A7	88%	61.952,16	71.734,08	-9.781,92	70.447,17	-8.495,01	0,86	0,88	92.693,64	6,95
A7	91%	74.179,56	74.179,56	0,00	72.848,77	1.330,79	1,00	1,02	80.053,60	6,00
A8	98%	77.032,62	79.885,68	-2.853,06	78.452,52	-1.419,90	0,96	0,98	83.018,54	6,22
A8	99%	79.885,68	80.700,84	-815,16	79.253,06	632,62	0,99	1,01	80.870,47	6,06
A9	100%	81.516,00	81.516,00	0,00	80.053,60	1.462,40	1,00	1,02	80.053,60	6,00

Figure 6: EVM values for the entire project.

The TAC (initial estimation of project duration) is 6 months, while BAC (initial estimation of project cost) is €81.516,00. The first activity (A1) required 18 solar days, according to the plan, and a total of 40 person/days (p/d) compared to 48 planned with a lower cost. The EVM indicators for this activity confirm this data. In A2, descriptive statistics show that actual values are lower than planned ones. The project was proceeding correctly and project managers decided to designate the extra budget to future activities. In A3, the activities were carried out in less time with respect to planned (27 solar days, and 60 p/d, compared to 30 solar days and 81 p/d planned). In accordance to the interpretation of the decision model, project managers decided to designate part of the budget not spent and the resources assigned to this task. In A4 the trend of EVM indicators confirms the results of the previous phases as they satisfy the baseline values of the decision model. As it appears from both the descriptive statistics and the EVM values, A5 was carried out with less effort and cost than planned.

In A6, when the milestone checkpoint was carried out, the project was behind schedule and not completed yet. At this point the EVM indicators pointed out a situation over budget as more than expected was being spent and project cost and effort were higher than planned. As improvement action managers decided to designate part of the resources saved in the previous phases to the current one. Consequently, staff that had terminated activities early and had the required skills were assigned to this activity. Also, part of the budget saved in the previous phases was also shifted to this one. This improvement action had positive effects, i.e. at the next milestone checkpoint the EVM indicators had returned within the baseline values. Having recovered both budget and resources from previous activities, the overall budget and effort for the project were not impacted. Indeed, the EVM indicators related to A6 are inline with the baseline values. This was possible because manager decisions in previous checkpoints were taken in order to prevent difficulties in further activities. In A7 another delay occurred. After a period of 54 days, the activity was not completed. The EVM indicators confirm this situation for A7 (Figure 6 first row), which are below the threshold values. Managers reallocating resources from previous activities or from activities that were ahead of schedule and below budget and shifted them to A7. For what concerns A8, after 12.6 days it was not completed (Figure 5). A9 requested fewer resources in terms of performances and cost to be carried out, and consequently indicators SPI and CPI returned to satisfy the baselines.

Having collected EVM values during milestones with a granularity related to activities rather than work packages or entire project, allowed the project managers to appropriately monitor and control the general trend of the performance indicators and readily act to recuperate delays accumulated during the project. Indeed, the resources saved in on-schedule/budget activities were allocated on other critical off-schedule/budget ones. As so, delays were mitigated by improvement actions without impacting on the overall final project cost and effort, which by the end of the project turned out to be within the expected thresholds. Deviations from the plan in some activities were successfully recovered in other ones by readily reallocating budget and effort to face problematic situations pointed out during monitoring checks. Having adopted a decision model to guide the interpretation of indicators turned out to be helpful as it simplified the entire monitoring and control process as the project progressed in time.

4 DISCUSSION AND CONCLUSIONS

Earned Value Management technique is easy to understand and apply. Nonetheless, there are several critical factors that any manager should keep in mind: collecting cost values at a low level of granularity requires an advanced level of management control, as costs must be broken down conformingly to the level of detail chosen; determining the percentage of completion of an activity requires "structured processes" and careful evaluations.

EVM allows to achieve an objective evaluation of risk and project status and, at the same time, provides useful indicators that allow to change management strategies, increasing or decreasing resources assigned to activities based on performances, in order to improve and optimize the general progress of the project in terms of cost and time.

Tracking earned value is of little value if the estimating and analysis capability that it provides is not used to operatively manage the project as it progresses. Furthermore, reporting real project status systematically, at regular intervals provides an opportunity to serve as early alarm and address potential problems readily, before it is too late and avoid cost overrun and schedule slippage. For this reason it is important that project managers adopt this approach and use the decision model for conducting project monitoring and interpreting the indicators collected in specific milestones and granularity entities, fixed at the beginning of the project, in order to prevent problems from occurring and promptly act when they arise.

EVM is not the silver bullet for project monitoring and control, however it surely provides a higher level of control on the project execution. Applying our proposal to a real case has pointed out how the classification in conceptual categories sheds light on the multitude of EVM metrics that a manager must handle during project monitoring activities. Also, the decision model supported managers in decision-making during the entire project. This technique, given its features is more appropriate for medium to large structured contexts rather than small and agile ones.

We are currently refining the decision model so it can be better tailored to any task, activity, phase, of a project and therefore be adapted to any desired level of granularity according to the project needs. It is also being implemented in a decision support system tool, as the model has been formalized in decision tables. This solution will provide automated support to project managers allowing them to monitor and control EVM values with less effort.

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