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PERFORMANCE MONITORING USING EVM INDICATOR: A STUDY CASE OF CONSTRUCTION PROJECTS IN THE PUBLIC SECTOR IN BRAZIL

MONITORAMENTO DE DESEMPENHO UTILIZANDO O INDICADOR DE EVM: ESTUDO DE CASO EM PROJETOS DE CONSTRUÇÃO NO SETOR PÚBLICO NO BRASIL

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Abstract

The control of performance through indicators is a very important management tool for companies. The EVM (earned value management) indicator has been used as a management tool in various types of projects. It has been widely used in construction engineering; however, some authors have identified differences in its use between theory and practice. The main objective of this paper is to compare the practice in the market to the theory of EVM in civil construction projects in the public sector in Brazil.

A study case was conducted of three construction pro-jects in the public sector. The results of the survey were analysed on the basis of a qualitative approach which indicated differences concerning the theory and practice of EVM. With the aim of verifying these dif-ferences, the applicability of the model was analysed from the point of view of relevance and adequacy. Later, a detailed study from the perspective of the training and practices of project management was conducted in the contracting companies.

Keywords: project management; EVM; earned value management; performance in civil construction.

1. INTRODUCTION

Kahn (2011) emphasizes the importance of research in order to improve performance in development projects in emerging countries. He describes the four BRIC countries (Brazil, Russia, India and China), referred to as the world's factory (China), the garden of the world (Brazil), the gas in the world (Russia), and the back office of the world (India). South Africa is added to the group of BRIC countries as the world's jeweller and is indicated as a gateway in Africa to the BRIC countries, having considerable experience in mining exploration, extraction and the processing of minerals.

Garces *et* Silveira (2002) outlines the legal mechanisms for disseminating the restructuring of all activities in the public administration in Brazil. They detail the form of integration of principles in project management in Brazilian public projects and define the position of the project manager and his/her main responsibilities, and describe how new legal mechanisms create the mandatory annual performance monitoring of Brazilian public projects.

Increased competition on a global scale and rapid technological development has caused companies to improve the internal controls of their own and their customers' projects (Kim *et al*., 2003).Indicators are essential management tools in monitoring and evaluating project activities, as they allow the achievement of goals to be monitored as well as advances and improvements in quality to be identified. To monitor the project is to compare the current with the planned situation, determining if the costs and the schedule are progressing according to plan, in order to take corrective action when needed (De Marco *et* Timur, 2013).The performance indicator in engineering projects is particularly important because it allows problems that may occur during the course of the project to be foreseen, enabling adjustments and corrections, as well as avoiding deviations from the plan. EVM (earned value management) is a powerful tool in managing scope, time and costs, allowing scheduled performance indices and costs to be achieved (Anbari, 2003).

Research conducted by the ICPMA (International Council for Project Management Advancement) (2002) shows that the EVM is the most used performance index in construction. Table 1 shows the percentage use of the indicator in each

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segment of the industry. Eighty per cent of businesses in civil construction use it, as do 76.47% of those in other engineering areas and 56.47% of those in IT (information technology). Construction is a type of complex project with many uncertainties; however, despite the different cost controls, the construction industry has adopted the EVM indicator to control cost (Al Jibouri, 2003).

Type of Project	Percentage of Responses
Civil Construction	80.00%
Engineering	76.47%
IT	56.47%
Defence	51.76%
Finance	32.94%
Processing	31.76%
Human Resources	17.65%
Other	8.24%

Table 1 – Percentage of EVM implementation by project type

Source: ICPMA (2002)

Despite being well known in the market, EVM application in projects is not simple. Depending on how the indicator is used, performance variations may occur disguising the real situation. It is necessary, therefore, to define appropriate processes to achieve earned value. It is important to consider the choice of a suitable methodology to monitor performance by using earned value (Fleming *et* Koppelman, 2010). According to Kim *et al*. (2003), the greatest problems in using EVM refer to understanding the methodology. According to the (PMI Standard EVM 2nd ed.,2011), for successful EVM use it is necessary for the company to have in place an information system, together with policies and procedures for its use, as well as proper training for the project team. According to Kim *et al*. (2003), the use of integrated software for project management is crucial to the success of EVM implementation.

In comparison with other industries, the construction industry has been left behind as far as the use of EVM is concerned. In addition, it has had difficulty in adapting the EVM methodology to practice (De Marco *et* Timur, 2013). According to Fleming *et* Koppelman (2010), the most worrying factor is the fact that many construction companies use the planned value of costs and the present value of costs without considering a third dimension, the aggregate value. According to Song (2010), the aggregate indicator is known in the construction industry as aggregate hours or aggregate dollars.

This research aimed to investigate whether differences exist between theory and practice in the use of EVM in the construction industry in the public sector in Brazil and the possible causes of this discrepancy.

2. EARNED VALUE MANAGEMENT

The earned value indicator evaluates the performance of projects in three key dimensions: schedule, scope and cost. These three dimensions are recognized by the PMI (Project Management Institute) as the "iron triangle" and their importance is recognized for their efficiency in project control PMBOK (2013). The earned value indicator is derived from the cost of each phase of the project. To ascertain the value of the indicators, the activities need to be quantified in terms of cost and completion dates for each task. According to Vargas (2008) the earned value technique meets the goal of linking time, scope and cost.

The EV indicator is ascertained from the completed activities and their associated value called EV. Figure 1 illustrates the baseline budget or planned cost, called the PV (planned value), the EV and the AC (actual cost).

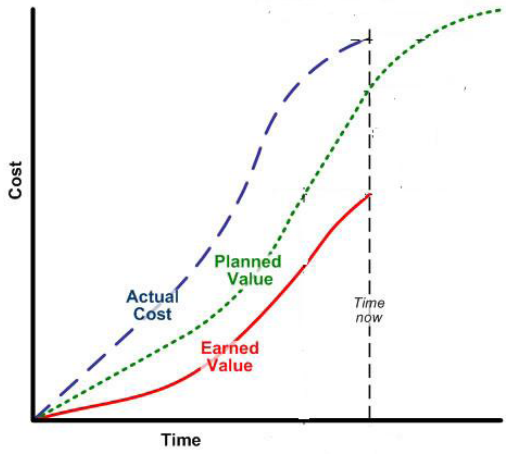

Figure 1 – EV graph

Source: Adapted by the author from Vargas (2008)

The ANSI / EAI 748 (1998) define 32 processes for the implementation of EVM; these processes were further simplified by PMI (Project Management Institute) 1996. According to Fleming *et* Koppelman (2010), this simplification brought great acceptance of the use of the indicator and can be fully utilized in projects of any size.

In the analysis of the implementation of procedures for EVM, it was also necessary to identify the main processes of the EVM of the companies selected. In Figure 2 details the main processes of the planning and operation cycles of the EVM.

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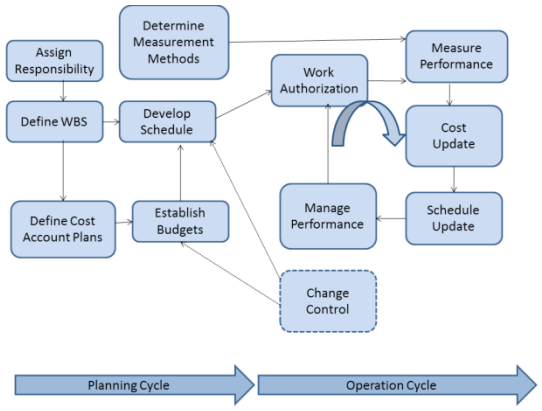

Figure 2 – Indicator value (EVM) processes.

Source: Adapted by the author from PMI Standard EVM (2011).

According to PMBOK (2013), to perform the tasks of the project it is important to divide the work into smaller pieces, so that it is easy to define and control. The lower parts of the division of scope are known as the WBS (work breakdown structure) and to establish the WBS it is necessary that all the previous processes and management projects are already completed, such as the project charter, strategy, stakeholder management, requirements documents and scoping.

According to Fleming *et* Koppelman (2010), the cost account plan should integrate the WBS with the work to be performed, allowing measurements of cost for each WBS item. The process to "define cost account plans" uses the division of work packages previously defined by WBS. Each work package will have an account code already defined by the WBS and will provide the basis for analysing the expenses.

According to Kerzner (2010), establish budget defines the cost of each item of the WBS, which in sum should be the total cost of the project. The budget shall include items of direct cost, indirect cost, materials and human resources for each activity and also reserve funds. This cost shall be allocated in the cost accounts plan defined previously.

According to De Marco *et* Timur (2013), develop schedule process defines the baseline schedule, setting the start and end dates of each activity of the project. The cost of each work package should be added to the schedule; therefore, the final schedule integrates the cost and timelines of the project and will be used to measure the baseline performance known as the PMB (performance measurement baseline).

According to PMI Standard EVM (2011), determine measurement methods process is clearly defined as quantifying each item. This measurement will depend on the type of contract and also the type of activity to be carried out. The types of activity are: discrete effort, shared effort and level of effort. Discrete effort can be broken down as: fixed formula weight milestones, per cent complete and physical measurement.

Kerzner (2010) argue that after completion of the planning processes, the operating cycle begins. In order to control the execution, it is necessary to evaluate the performance variation, considering the work done within the established period of measurement. The change in project performance is ascertained by comparing the predicted value (baseline design) with the amount realized .When starting the operation cycle, the work authorization document must be issued.

According to Fleming *et* Koppelman (2010), In accordance with performance in the time period, the schedule, aggregate costs and actual costs should be updated. The update of the actual cost must include the cost of materials and services during the evaluation period. Each cost item should have been previously established in the account plan.

According to De Marco *et* Timur (2013), the manage performance process the value of the cost performance indicator, CPI (cost performance index), and schedule performance indicator, SPI (schedule performance index), will be evaluated.

The change control process provides the controls to change the project and still provide corrective measures in the event of deviations in the time and cost indices (PMI Standard EVM, 2011).

Lipke (2013) argues that despite the fact that EVM has been used for the last 40 years, its use is not simple and requires complex management that involves schedule control, precise control of costs and control of the aggregate value (work done). The author further argues that the classification of maturity in project management by OPM3 (Organizational Project Management Maturity Model) using indicators begins at maturity level 2 (managed) and evolves to higher levels.

Research developed by Vargas (2003) in three constructions projects identified the following critical factors for EVM use: management support, team qualification and defined project scope. According to Valle (2006), the critical factors for EVM use are: indicator report, schedule control, assigning responsibilities to each item in the WBS, management support, team qualification, scope well defined, workflow and activities, continuous learning process. According to Kim *et al*. (2003), the training in and practice of EVM are critical success factors. Fleming *et* Koppelman (2010) argue that, for the use of such an indicator, it is necessary for the company to be mature enough. It appears that maturity in project management and training in EVM are common requirements among the authors cited in this article.

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3. PROJECT MANAGEMENT MATURITY

Some maturity models in project management have been developed by the scientific community: all models are based on the idea of assessing organizational competence in performing project management activities. Kim *et al*. (2003), Song (2010), Lipke (2013)

Project management maturity, according to the PMBOK (2013) model, is based on OPM3 (2013). The levels of maturity defined are:

• Level 1 – The use of project management practices in the organization are practically non-existent. There is no interest in recognizing the benefits from the use of project management practices. When there is some recognition, it is merely to meet certain requirements for a client in hiring the services of the organization.

• Level 2 – The need to implement processes and methodologies that support project management and measuring indicators are perceived. The importance of acquiring knowledge in project management is recognized. Project Managment covers scope, time and cost.

• Level 3 – The processes are integrated and there is support from top management. Project management methodologies based on guides and checklists are used. Training in project management is continuous. Project management is part of the company's culture and its benefits are recognized.

• Level 4 – A project management office is established and this is dedicated to continuous process improvement and project documentation. Measurements (benchmarking) covering the quantitative and qualitative aspects of the projects are undertaken.

• Level 5 – Project management is optimized and continuous improvements from lessons learned are documented and used in projects. There is continuous strategic planning for project management.

It was verified that, according to the levels previously described, measurement with the indicators starts only from level 2 of maturity.

According to the research into maturity in project management undertaken by Prado (2012), the average maturity in construction companies is low according to the assessment made in 2012.

4. METHODS

The research has been characterized as applied or technological because it creates products and processes for immediate and practical application, as far as performance indicators in projects and engineering works are concerned. The approach is exploratory as it attempts to clarify facts seeking greater familiarity with the problem. The relevance in the scientific international literature is presented by Figueiredo (2009) who highlights the shortage of conceptual contributions as well as of management contributions. The latter focused on the improvement of design, implementation of empirical research and innovation strategies in project management from the perspective of technological learning in the context of emerging economies. Such a view will hopefully contribute to enlarging the comprehension of the complex process of technological development as well as of project management.

The sequence of the methodology used is shown in figure 3.

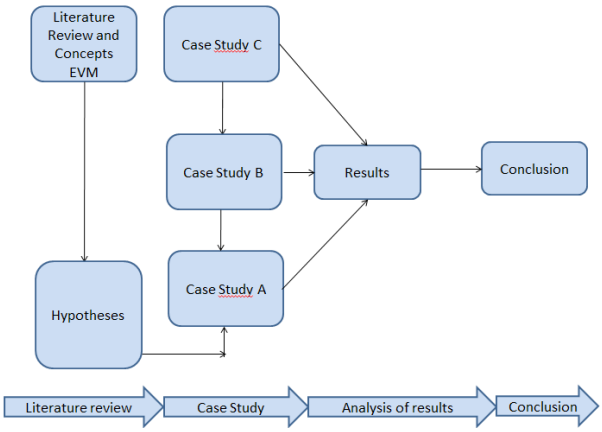

Figure 3 – Methodological sequence

Source: Authors 2014

Initially, the literature on the subject will be reviewed and a problem situation will be formulated and then hypotheses built. Finally, through study case, the differences mentioned in the literature identified.

The results were validated through study case with a qualitative approach, where observation as well as document revision and informal interviews with engineers and technicians in the planning sectors of companies were used. The study case was conducted in three civil constructions in the public sector and occurred between 2012 and 2013, in the State of Rio de Janeiro in Brazil.

In the analysis of the implementation of procedures for EVM, it was also necessary to identify the maturity in project management of the companies selected.

This research attempts to answer the following question:

Are there differences between the theoretical model and the practical use of the earned value performance indicator in civil construction in the public sector in Brazil?

According to Leedy (2000), after defining the problem, the next step is to formulate the hypotheses that could

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answer the proposed problem and guide the next steps of the research. To answer the central question the following hypotheses are formulated:

- H1 - The Company considers EVM use relevant: The company has a perception about the importance of using the EVM for project performance.
- H2 - Usage the EVM Theoretical Model: The EVM theoretical model is used by the companies.
- H3 - The Company considers EVM use adherent: It is understood that it is possible that the proposed EVM analytical models are appropriate to the needs of construction companies in measuring performance.
- H4 - The Company considers EVM use complex: The complexity of the models, states that EVM models are complex and difficult to understand.
- H5 - The Company considers EVM difficult to operationalize: Operationalization difficulty implementation of EVM by the companies.
- H6 - The team don't have qualifications in EVM. The companies have no qualified personnel to implement the earned value indicators.
- H7 - The Company do not have maturity in project management. The companies do not have no maturity in project management a find difficulty to implement the earned value indicators.

After the hypotheses definition, a set of variables have been defined. According to Bacharach (1989), variables are observed units and constructors are approximate units that can not observed directly.

The table 2, define hypothesis as constructors, variables and evidences for field research.

Hyp	Constructos	Item	Variables	Source of Evidence
H1	The company considers EVM use relevant.	1	Relevance of Evm using.	Interview
H2	Usage the EVM Theoretical Model	2	The formulas for calculating the performance indices and the graphics were in accordance with the theory.	Documentation
		3	WBS defined.	Documentation
		4	Cost account plans (CAP) defined.	Documentation
		5	Budgets established.	Documentation
		6	Measurement methods determined.	Documentation
		7	Schedule developed.	Documentation
		8	Work authorization.	Documentation
		9	Work performance	Documentation
		10	Schedule updated	Documentation
		11	Cost updated	Documentation
		12	Manage Cost Performance	Documentation
		13	Manage Schedule Performance	Documentation
		14	Change control	Documentation
H3	The company considers EVM use adherent.	15	Adherence to EVM	Interview
H4	The company considers EVM use complex.	16	Complexity to EVM	Interview
H5	The company considers EVM difficult to operationalize.	17	Difficult to operationalize EVM	Interview
H6	The team has qualifications in EVM analysis.	18	Qualification of the team for the EVM	Interview, Documentation
H7	The company has maturity in project management.	19	Team maturity in project management	Interview, Documentation

Table 2 – Constructs, variables and evidence source

Source: Authors 2014

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4. CASE STUDY

In order to evaluate the practice of the construction industry in the use of project performance using EV analysis, three construction projects were analysed.

The projects were carried out in Rio de Janeiro in the period 2012 to 2013. The firms were large companies in different sectors (energy, airport infrastructure and public health), all with nationwide coverage.

The selected projects were analysed through documentary research, unstructured interviews and field observation and the projects are summarized in Table 3.

Item	Project 1 (Company A)	Project 2 (Company B)	Project 3 (Company C)
Scope	Road access to equipment, 18 km long with 15 bridges.	Enlargement of airport runway.	Administrative office building with 4 floors.
Start	10/01/2012	29/10/2011	02/04/2012
Time	24 months	24 months	23 months
Budget	U$ 79,100,000.00	U$ 26,700,000.00	U$ 18,600,000.00
Industry	Energy	Airport infrastructure	Public health
Type of company	Public	Public	Public
Company size	Large	Large	Large
Contractor segment	Civil construction	Civil construction	Civil construction
Contract type	Fixed-Price	Fixed-Price	Fixed-Price
Software used	MsExcell, MsProject	MsExcell, MsProject	MsExcell, MsProject

Table 3 – Projects from Case Study

Source: Authors 2014

The projects selected are from different scope: road access to equipment, enlargement of airport runway, administrative office building. The company size is Large from civil construction segment and fixed-price contract. The software use is MsExcell and MsProject.

5. RESULTS

Table 4 summarizes the data from the interviews and observation in documents conducted during project execution. The interviews followed to verify the hypothesis of: relevance, use of theoretical model, adherent, complexity, qualification in EVM, operational difficulty and maturity in projects.

From the literature review and the results of study case, the intention was to find differences between the theory and practice of EV in construction. Table 3 analysed the implementation as regards the theory of EV and Table 4 analysed the relevant information regarding the companies involved.

Item	Variable	Project 1	Project 2	Project 3
1	Relevance of using Evm.	Yes	Yes	Yes
2	The formulas for calculating the performance indices and the graphics were in accordance with the theory	Use formulas and graphical View	Use formulas and graphical View	Use only graphical View
3	WBS defined	Use WBS	Don´t use WBS , only a list of material	Don´t use WBS , only a list of material
4	Cost account plans (CAP) defined	Use CAP	Don´t use CAP	Don´t use CAP

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5	Budgets established	Budgets was established	Budgets was established	Budgets was established
6	Measurement methods determined	Use measurement methods	Use a list of material with costs and methods	Use a list of material with costs
7	Schedule developed	Schedule develop according WBS	Schedule develop according WBS	Schedule develop without WBS
8	Work authorization	Use Work authorization	Sometimes use Work authorization	Don't use Work authorization
9	Work performance	Analyse work performance monthly with EVM and Report Performance	Analyse work performance monthly with EVM and Report Performance	Analyse work performance only with graphical view
10	Schedule updated	Schedule updated monthly in accordance with physical work	Schedule updated monthly	Don't update schedule
11	Cost updated	Don't update cost	Don't update cost	Don't update cost
12	Manage Cost Performance	Don't manage cost	Don't manage cost	Don't manage cost
13	Manage Schedule Performance	Manage Schedule Performance and analyse results	Manage Schedule Performance	Don't manage Schedule performance
14	Change control	High	Low	Low
15	Adherence to EVM	Yes	Yes	Yes
16	Complexity to EVM	Yes	Yes	Yes
17	Difficult to operationalize EVM	Yes	Yes	Yes
18	Qualification of the team for the EVM	High	Medium	Low
19	Team maturity in project management	Yes	Yes	No

Table 4 – Results

Source: Authors 2014

The companies were analysed and the hypotheses formulated were validated based on the information of each company in Table 4.

Item 1 (H1) refers to the relevance of EVM as considered by all the projects.

Item 2-14 (H2) relate to usage the EVM theoretical model the analysis of the results in Table 4 shows the best use of EVM theory in Company "A", followed by Companies "B" and "C". As the literature review, De Marco, Timur (2013) also identified the difficulty in usage the EVM theoretical model.

Item 15 (H3) refers to the adherence of EVM and whether the proposed analytical models for EVM were considered suitable for construction companies in measuring performance.

Item 16 (H4) refers to the complexity of the EVM methodology, it was noted that the companies in general considered EVM theory to be complex. As the literature review, Kim *et al*. (2003) also identified the difficulty in operationalizing EVM.

Item 17 (H5) refers to the difficulty in operationalizing EVM, it was found that companies in general considered EVM difficult to operationalize. As the literature review, Fleming *et* Koppelman (2010), Lipke (2013), De Marco *et* Timur (2013) also identified the difficulty in operationalizing EVM.

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Item 18 (H6) refers to qualification of the team, it was greater competence was found in Project 1 and less in Project 3. Therefore compare the results from usage the EVM theoretical model (Item 2-14) and qualification of project team (item 18) it is noted that the team with better qualification use better the theoretical model. As the literature review, PMI Standard EVM 2nd ed. (2011), Kim *et al*. (2003), Vargas (2003), Valle (2006) also identified the importance of the team qualification.

Item 19 (H7) refers to team maturity in project management; it was observed that Project 1 and 2 were mature in project management. As the literature review, Fleming *et* Koppelman (2010) also identified the importance of the team maturity in project management for EVM use.

6. CONCLUSIONS

The answers to the question proposed by the research and the evaluations of the formulated hypothesis can be reached by using qualitative research, including field observation, informal interviews and document analysis of the companies and of the construction projects studied.

Are there differences between the theoretical model and the practical use of the earned value performance indicator in civil construction in the public sector in Brazil?

Yes, it has been found that there are differences between EVM theory and practice. This study has shown that the gap between theory and practice in EVM.

Hypothesis 1 – Relevance

Analysing the results regarding relevance, it has been confirmed in the three companies surveyed that there is a perception in those companies about the importance of using EV analysis for project performance.

It was also observed that, despite not using EVM properly, the companies profited from its use because, in addition to the graphic view, they were also be able to anticipate problems in the projects through the time and cost performance indicators.

Hypothesis 2 – Usage the EVM theoretical model

Relate to usage the EVM theoretical model the analysis of the results in Table 4 shows that the companies don't use the EVM Theory completely. The best use of EVM theory in Company "A", followed by Companies "B" and "C".

Hypothesis 3 – Adherence

It was observed that the companies consider EVM appropriate to their needs, enabling them to control the cost associated with the project scope and to schedule the project. However, they consider the EVM methodology complex and difficult.

Hypothesis 4 - Complexity.

It was observed that all companies consider the theory of complex EVM.

Hypothesis 5 - Difficult to operationalize.

It was found that companies in general considered EVM difficult to operationalize.

Hypothesis 6 – Qualification

According to the information in Tables 4, the companies with more qualifications were better able to meet the EVM requirements. We can therefore infer that training of staff is of fundamental importance in EV being used properly. Understanding EV involves knowing project management, construction costs and EV theory.

Hypothesis 7 – Maturity in project management

According to the information in Tables 4, the companies with greater maturity in project management were the ones that were better able to meet the requirements analysed for EVM. Maturity in project management is the most important item for the EVM to be fulfilled properly.

Although the research was conducted with a limited number of companies, given the same representative and regular results, we can infer that correct EV implementation is directly related to maturity in project management and the training of the staff involved.

A correlation was noted between maturity in project management and training in the correct application of the concepts of EVM, because the companies with greater maturity in project management and training have better conditions to achieve project goals based on the project management triangle (scope, time and cost).We can therefore infer that maturity in project management and training of staff is of fundamental importance for EVM. Training in EVM includes knowledge of project management, the cost of work and EVM theory.

It was verified that most of the companies had difficulties in the operation cycle of the project, when the aggregate and the cost curves are required. It was also observed that the use of software in integrating EV analysis is a factor that could make EVM use easier.

The research confirms other EVM surveys, quoted at the beginning of this article and conducted by authors from different countries, and deepens the theme of the use of the EV indicator. The development of new studies in other research is proposed, with several companies of different sizes to extend and confirm the findings obtained in this research.

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