CRITICAL ANALYSIS ON EARNED VALUE MANAGEMENT (EVM) TECHNIQUE IN BUILDING CONSTRUCTION

Luis Felipe Cândido[1], Luiz Fernando Mählmann Heineck[2] José de Paula Barros Neto[3]

ABSTRACT

Earned Value Management (EVM) is a technique of performance measurement focused on project physical, financial and time progress, indicating planned and actual performance, variations of them and forecasts on final project duration and cost. It takes a step further traditional measurement tools like PERT/Cost and C/SCSC. EVM is strongly supported by Project Management Community gather around the Project Management Institute, but recently the technique is being criticized in respect to its conceptual problems and implementation difficulties. This paper aims to explore in greater depth this debate through a case study on a construction project that applied EVM as a planning and control tool. Four major problems are analyzed in the search for an enlarged list of topics the EVM approach fails to support lean construction applications. Among them are the disregard for the mobilization of resources phase and the lack of consideration of construction indirect costs. Finally, the authors concluded that EVM is just an extension of the traditional approach of measuring physical and financial advances over time. This narrow approach is insufficient to provide a comprehensive managerial tool, as became clear through the analyses of the building project under consideration.

KEYWORDS

EVM (Earned Value Management), Control of Building Projects, Lean Construction and Project Management.

INTRODUCTION

Uncertainty and complexity typical of constructions projects led building companies to adopt more sophisticated techniques and tools to effectively plan and control building developments. Normally these techniques are connected to cost management due to its importance in project performance.

The theory on planning and control evolved intensely during the fifties, with the introduction of CPM and PERT. Only by the nineties controversy could be supported by structured reasoning associated with the up rise of Lean Construction Theory due to the seminal research work (Koskela, 1992).

Lean Construction Principles allowed old managerial paradigms to be broken, bringing innovation and continuous improvement to building process monitoring. A

[1] Master Student, Federal University of Ceará (UFC), Brazil, luisf_civil@yahoo.com.br
[2] Lecturer, State University of Ceará (UECE), Brazil, feritas8@terra.com.br
[3] Lecturer, Federal University of Ceará (UFC), Brazil, jpbarrps@ufc.br

proactive management style leading to agility and responsiveness to changes demanded by customers and by the market can now benefit from two different views on how to assess building performance, briefly described in what follows.

Traditionally, measurement in the construction industry is catered by surveying physical progress and their incurred costs. Gantt charts suffice to maintain physical and financial accounts on how estimates of building activities are under way. A well-established criticism to this naïve approach is found in a great number of authors (Bassioni 2004, Nudupurapati et al. 2010, Too and Ogunlana 2010, Horstman and Witteveen, 2013).

Alternately, the Earned Value Management Technique (EVM) or Earned Value Analysis (EVA) emerged. Developed by the US Defense Department, this technique is widely used as tool of control and it is indicated by the Project Management Institute (PMI) as a standard tool for project performance measurement. The PMI provides an historic view on the evolution of this technique departing from the initial efforts with PERT/COST (1962, 1965, and Cost Schedule Planning and Control Specification - C/ SCSC (1967, 1996). Major advances are the integration of planning, control and definition of project scopes into a single tool. (Fleming and Koppelman 2010, Mattos 2010).

EVM focus on forecasting final costs and project duration, what is deemed crucial to alert managers and enforce their reaction to overcome delays and costs overruns. Management tools that might bring project again on schedule are not provided by the EVM technique, but it might be taken that they do not exceed what is normally available in the manager's tool box. This is to say that the analyses of variations and a clear display of project goals are the key elements to trigger standard management efforts that would naturally induce appropriate decisions leading to project success (PMI 2005, Acebes et al. 2013).

However, even in face of this supposedly overwhelming easy of adaptation to project management needs, critics were able to find information domains that are not covered by this tool: such domains might inhibit the provision of data on project progress status that are useful for practioners of different current of thoughts in planning. Kim and Ballard (2000) analyzed the applications of EVM technique in the construction industry from the perspective of workflow. They concluded that the EVM is an inappropriate tool to monitor workflow, a cornerstone conceptual basis of lean construction. Furthermore, EVM addresses value from the perspective of the developer or building company, only indirectly generating views of final value that are of interest for final clients.

White and Fortune (2002) analyzed barriers and difficulties to the adoption of EVM. regarding the managerial process. Conclusions were that EVM is: (1) inadequate for complex projects; (2) too time consuming and bureaucratic for documentation (3) prone to failure in long term predictions; (4) heavily dependent on following standardized procedures, lacking a holistic view (5) difficult to implement; and (6) difficult to use after implementation.

Narbaev and De Marco (2013) analyzed traditional EVM methods to Estimate Final Costs at Completion (EAC), indicating that they were unreliable on project early stages. A sophisticated mathematical model was proposed, what do not add simplicity and easy of understanding as required for management techniques that might end up being used at the shop floor.

Another evidence of inadequacy of EVM tools is related to potential errors while forecasting performance at the level of stages of work rather than the project as a whole (Vandevoorde and Vanhoucke, 2006)

EVM TERMINOLOGY

PMI (2005) classifies EVM terminology into two categories: (1) key parameters of EVM, including Planned Value (PV), Earned Value (EV) and Actual Cost (AC), and (2) EVM measures (variances, indices and forecasts).

Key parameters are straightforward in their formulation. Planned Value (PV), also known as the Budgeted Cost of Work Scheduled (BCWS), represents an initial estimate for planned work. It is the typical information provided on Project Budgets and produced by estimating departments. It is provided by quite well established procedures to evaluate planned costs and has been incorporated by EVM to enhance the set of tools their practioners are able to offer in their consulting work. It is based on a Project Breakdown Structure that does not necessarily follow the set of operations that would flow on site. Site planning will inform the expected amount of budgeted work that should be accomplished according to a progress elapsed duration.

Earned Value (EV), also known as Budgeted Cost of Work Performed (BCWP), represents the amount of work that has actually been accomplished to date, expressed as the initial budget for that work. For the moment, it should be mentioned that such figures of Planned and Earned amounts to be called value should be at least correct in terms of estimating procedures. Moreover, if it is to represent value for the client, this can only be accepted with the indirect help from microeconomics: if it has rationally been accepted as the amount of money to be paid for the project, total estimated price and value might be equated according to client's views.

Actual Cost (AC), also known as the Actual Cost of Work Performed (ACWP), represents true cost of work performed to date. In order to provide feedback information on actual costs, planning and control systems should be equipped with company accounts linkages or other mechanism to estimate and take notice of real costs (PMI 2005, Fleming and Koppelman 2010).The timely evaluation of actual costs might prove to be a major burden to apply EVM. It can be said that during the course of a project only estimates of real costs are available, with their inherent probability nature in terms of accuracy.

EVM measures, the second category of terms to be defined, make use of a combination of previous key parameters. Schedule Variance (SV) is calculated as $SV = EV - PV$. It represents how much the project is ahead ($SV>0$) or behind ($SV<0$) schedule. As both EV and PV use cost estimates taken from the initial budget, SV takes care of time performance. Notwithstanding, it might happen that the project is taken as behind schedule ($EV<PV$) due to errors in the initial budget. Suppose that a great number of out of schedule activities was performed but their cost was underestimated and that overestimated scheduled activities were left behind. SV calculations will inform that a great amount of costs should be already allocated, due to the overestimated scheduled activities, what will not be compensated by the underestimated out of schedule activities that were actually performed.

Cost Variance (CV) CV is calculated as $CV = EV - AC$. It represents how much the project is under ($CV > 0$) or over budget ($CV < 0$) (PMI 2005; Fleming and Koppelman 2010). It essentially measures cost variations, but is also subjected to errors for initial estimates in connection to EV. As AC should be evaluate with real costs during various stages of construction, there is a burden on the cost control system to produce such figures, what might end up in calculating AC through another set of estimates of actual costs.

Schedule Performance Index ($\mathrm{SPI} = \mathrm{EV}/\mathrm{PV}$) represents the rhythm of production, i.e, the rate of converting planned cost into earned value. It provides the same information as SV, but now in relative terms. It varies around 1: SPI greater than one indicates that time performance is better than expected. Sources of inaccuracy for this index are the same as discussed for SV.

Cost Performance Index (CPI=EV/AC) represents how efficiently resources are being used. CPI represents the rate of converting AC in EV (PMI 2005, Fleming and Koppelman 2010). A CPI smaller than 1 indicates that the project is heading to a cost overrun, since what has been achieved do not correspond to what has been estimated, for the same set of activities. The only explanation is that costs are increasing in comparison with what has been estimated, or as before for CV, activities whose costs are added up to comprise EV were overestimated in the initial budget.

Forecasts are best summarized in Table 1.

Table 3 - Forecasting Indicators by EVM technique

Indicator	Equation	Interpretation
Budget at completion (BAC)	-	BAC represents total budget at completion; at completion PV=BAC
Estimate at completion (EAC_t)	$\mathrm{EAC}_t = \frac{BAC/SPI}{BAC/\,months}$	The estimated completion time for the project if the work continues at the current rhythm
Estimate to complete (ETC)	$^{1}\mathrm{ETC} = \mathrm{BAC} - \mathrm{EV}$	Cost to complete the project if all packages remain achieving the goals of time and cost, irrespective of what happened to EV
	$^{2}\mathrm{ETC} = \frac{BAC - EV}{CPI}$	Cost to complete the project assuming that current cost performance will remain the same (as occurred up to EV) throughout the rest of the project
	$^{3}\mathrm{ETC} = \frac{BAC - EV}{CPI \times SPI}$	Cost to complete the project assuming that current performance cost and schedule performance will remain the same as occurred up to EV) throughout the rest of the project
Estimate at completion (EAC)	$^{1}\mathrm{EAC} = \mathrm{AC} + \mathrm{BAC} - \mathrm{EV}$	Final cost of the project based in the original budget. The optimistic scenario assumes that all remaining work will be performed just with what remains on the initial budget.
	$^{2}\mathrm{EAC} = \mathrm{AC} + \frac{BAC - EV}{CPI}$	Final cost of the project if current performance trends to CPI continue. The realistic scenario assumes that all work remaining will performed with the actual CPI.
	$^{3}\mathrm{EAC} = \mathrm{AC} + \frac{BAC - EV}{CPI \times SPI}$	Final cost of the project if current performance trends to CPI and SPI continue. The pessimistic scenario assumes that all work remaining will performed with the actual CPI and SPI, both in terms of cost and durations.
Variation at completion (VAC)	$\mathrm{VAC} = \mathrm{BAC} - \mathrm{EAC}$	Cash balance at completion
To-complete performance index (TCPI)	$TCPI = \frac{BAC - EV}{BAC - AC}$	CPI to recover cost variances from the moment EV and AC are evaluated up to project completion

Legend: [1]optimistic scenario; [2]Realistic scenario; [3]Pessimistic scenario.

Figure 1 shows graphically EVM terminology as discussed above. Three major calendar dates are depicted: present moment (when initially PV, EV and AC are calculated), completion scheduled date and forecasted schedule date.

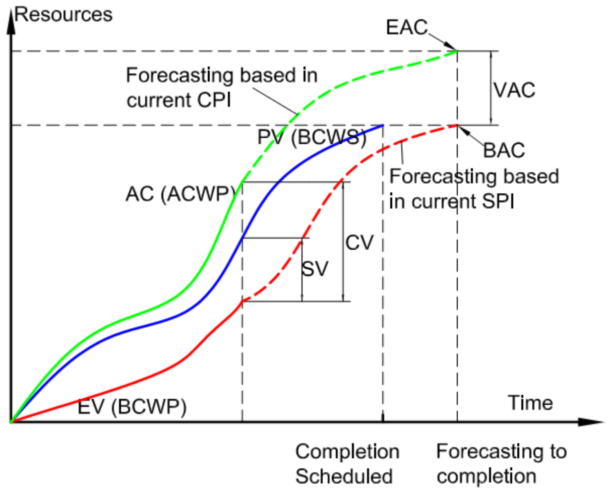

Figure 1: EVM main variables, variances and forecasting simulations.

METHODOLOGY

The strategy applied in this research was the case study approach. Yin (2010) defines the case study as an empirical investigation which allows analyzing one contemporary phenomenon in its real life context.

Regarding research aims, this work is characterized as exploratory research with quantitative data. In this research, generalizations were realized from particular cases to theory and are classified as basic, due to the fact that their use can help a better understanding on how to use EVM in a lean construction environment (Collis and Hussey 2005).

DESCRIPTION OF THE COMPANY AND THE PROJECT UNDER INVESTIGATION

A business tower with 20547.72 m² of constructed area was examined. The building has 26 floors distributed in 18 pavement types, parking, ground floor, 3 floors underground and attic pavement. In total, there are 234 commercial rooms.

Figure 2 shows floor layout and a view for the Tower Block.

Figure 2: Floor Layout and View for the Tower Block

The project started in December of 2010 and conclusion was scheduled to July of 2013, 3 months later than programmed. The facade area in glass skin with some 500m² was the special technical challenge for this project, as the building company was not acquainted with its setting into place.

The stakeholders (constructor and promoter) firmed a contract for the overall price of US$16.645.448, 04. A consultancy company on planning and control was contracted to give managerial support for the builder during the whole project.

The consultancy company is acquainted with lean thinking, Toyota Production System (TPS) and Theory of Constraints (TOC). Furthermore, they claim using the PMBOK guide from the Project Management Institute.

Consulting services are budgeting, logistical planning of construction site, programming and control of production. Budgeting was performed using the same packages of work that were further employed for site planning purposes.

Logistical planning was performed based in Lean Construction principles as to reduce the share of non-value adding activities. In terms of building planning Line of Balance was chosen as the site programming tool.

Monitoring and control of production was made possible by the use of a set of tools like analysis of productivity, PPC measures, costs control and the EVM measures discussed earlier (Earned Value (EV), Cost Variance (CV), Schedule Variance (SV), Schedule Performance Index (SPI), Cost Performance Index (CPI) and Estimate at Completion (EAC)).

Three synthesis documents were produced to present project performance at the end of each month: a trend analysis of two interim fortnight reports, a monthly report and a visual management dashboard.

RESULTS AND DISCUSSION

Three different project stages (building periods) were taken into consideration in order to properly assess progress on site, according to Casarotto (1996): 1) Mobilization of resources: in early stages, projects need to mobilize resources and establish site layout facilities. At this stage, physical progress is small but human effort and money spent are relatively high. This mobilization phase took the period from the start of the project to 30% of its scheduled total duration; 2) Stabilized workflow: at this stage consumption of resources and pace of production achieves stability. This period took encompass project activities performed within the 30% up to the 80% of the whole scheduled duration; 3) Demobilization of resources: at this stage the level of resource utilization falls gradually up to the total demobilization of resources at project completion. This final stage occurred from 80% up to the end of the project scheduled duration.

Figure 3 presents total monthly cost and the total cumulative cost at initially scheduled.

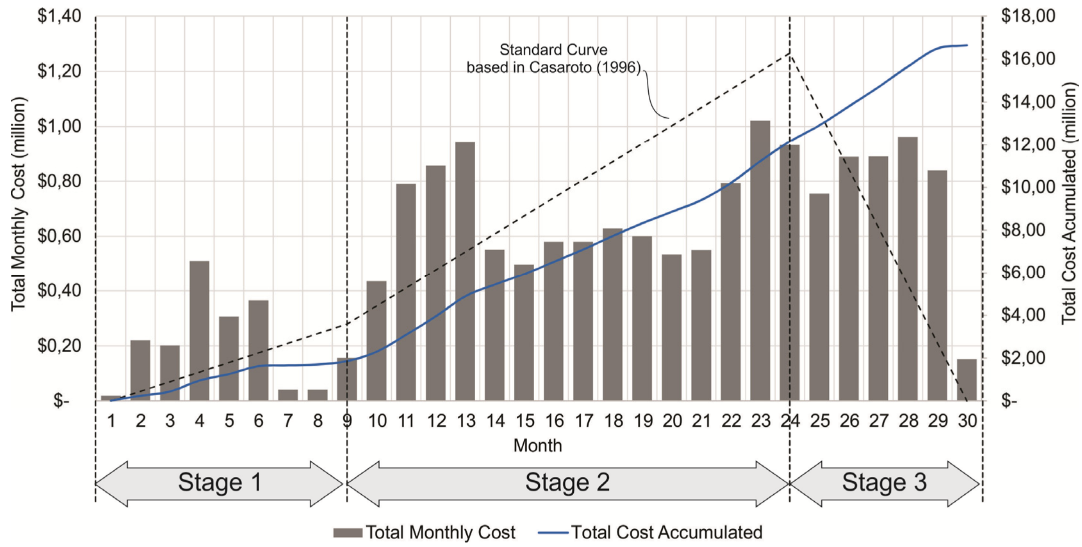

Figure 3: Total monthly cost and total cumulative cost as scheduled

It can be observed that application of resources was performed principally during stages 2 and 3: 11.19% of the total cost was allocated during the mobilization of resources, 61.84% during the second stage and 26.97% in the last stage. Casarotto's planned use of monthly expenditures was adopted to easy cash flow considerations. During the initial stage and part of the second stage the building company was accumulating cash from sales in order to maintain a better pace of work towards the final stages of construction.

ACTUAL S CURVE AND EVM ANALYSIS OF PROJECT PERFORMANCE

Figure 4 presents three different S curves that synthetize analysis using the EVM approach.

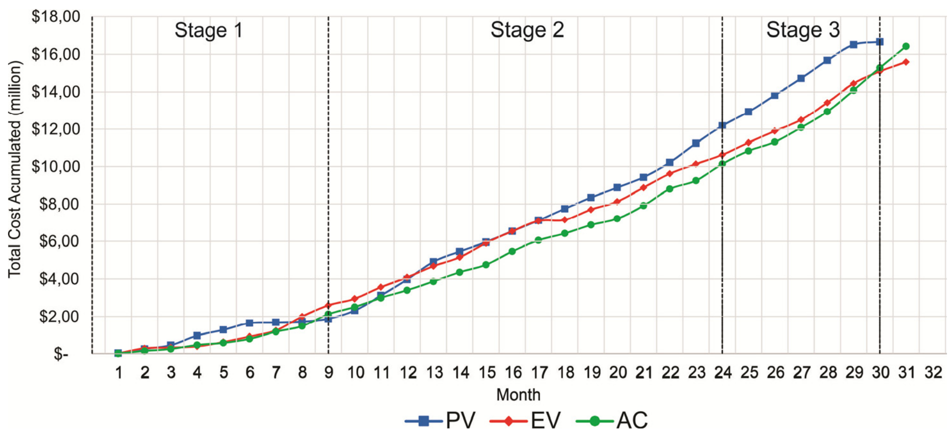

Figure 4: EVM and PV, EV and AC S Curves

It can be observed that actual cost was under earned value during 27 periods. This represents a good performance of CPI (in average 1.10). It means that the building company was able to operate under budget. As PV is most of the time above EV it means that progress was slow. As a consequence, SPI achieved a low performance (on average 0.89). This represents an eminent delay for total project duration.

This trend was confirmed. The project was completed 3 months later than expected, totaling 33 months of duration. Regarding this final duration, Figure 5 presents how much the Estimate at Completion (EACt) was forecasted above or under the initial planned deadline.

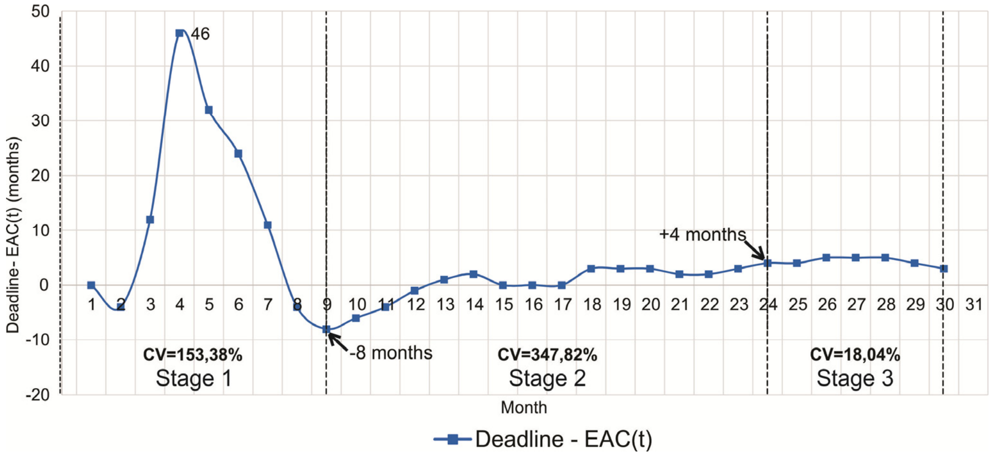

Figure 5: Estimate at Completion - Forecast for Final Duration

High coefficients of variation for forecasts on final duration were found for Stages 1 and 2. For example, in absolute terms total estimated duration in the 4th period of time was 46 months above the final scheduled duration. Its represents a total duration of 76 months (4 performed + 26 to initial deadline + 46 months above the schedule planned). In the 9th period of time the estimate was -8 months, i.e., 8 months earlier than initially scheduled.

These estimates produced a management overload to site agents regarding reprogramming of project schedule. Furthermore as managers could not evaluate the quality of their production processes, as progress on site pointed to such discrepancies in final project due date, they turned to other process performance indicators not supplied by the EVM tool box, like PPC and productivity analysis.

Figure 6 shows how much variation at completion (VAC) represents in terms of initial budget.

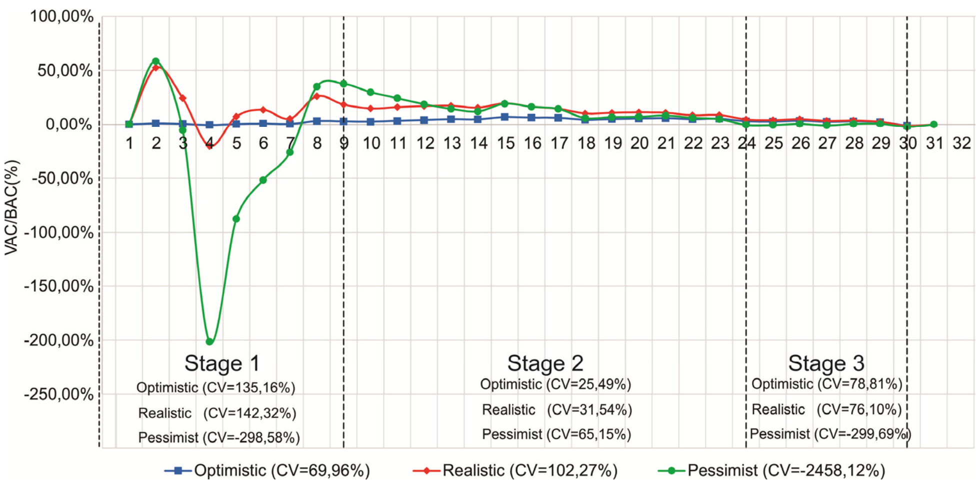

Figure 6: VAC/BAC analysis

Once more there is a high value for the coefficients of variation for predictions of final cost overruns. Take the realistic estimation, in month 2, $VAC = \$\,8{,}729{,}550.33$ what represents 52.44% of total budget cost. One month later this forecast was $VAC = \$4{,}048{,}562.22$, i. e., 24.32% of total budget cost, and half the amount forecasted before. Both of them are very doubtful in the sense that a project most probably will not be completed with 52.44% or 24.32% of its initial budget. With such variability it is difficult to take management decisions to keep project on tract and appraise the consequences of such decisions.

VALUE-ADD IN LEAN CONSTRUCTION X EARNED VALUE IN EVM

According to EVM Earned Value (EV) is the budgeted cost for work performed, i.e., how much work performed so far would cost according to initial budget (PMI 2005, PMI 2008, Fleming and Koppelman 2010, Mattos 2010). It is a monetary value with no direct connection to the value concept in Lean Construction. As already mentioned it might have and indirect relation if microeconomics are brought to the discussion.

If clients are willing to pay for a project with such initial budget (and every stage of work at its budget value) it means that they value it at this price. If the contractor was able to put work into place at this monetary amount it might be taken that the client will benefit from this. It is always the point discussing what the use is for a client of just parts, stages of work completed, as compared to the advantages of the whole facility ready for operation.

The language used in Lean Construction is different from the language used in EVM. Lean Construction deals with physical progress in terms of man-hours or quantity of service, productivity of labor, completion of specific parts of a project and the like. It avoids using money as a measure of all things. On the other hand EVM focus on monetary expressions of performance. For example, EV represents how much work was performed, but the indicator is presented in terms of cost of such work as expressed in the initial budget and not by any physical measure of what has been achieved, like the amount of concrete that was poured or how many hours were spent handling materials.

INSUFFICIENCY OF PROCESS INDICATORS AND QUALITY OF CONSTRUCTION

EVM leading indicators do not provide indicators on quality of construction or quality of processes. They report only the conversion performance, that is, how much of what was planned was achieved and how much is left to still be performed up to the end of the project. On the other hand, Lean Construction deals with the quality of products and processes, insofar as external and internal clients attribute value for such characteristics.

INCOMPATIBILITY FOR EARLY STAGES OF WORK PROGRESS FORECASTS

During the first stages of construction high variability was observed in connection to final costs and durations. EVM should recognize that this is not a proper moment to make forecasts, as it is known that physical progress is not proportional to money spent on site. For example, Cooke (1980) proposed that for an initial 10% physical progress on site it might be expected 16% of consumption of total project duration. As cost is used as parameter for progress measures in the EVM technique, an evident distortion of real progress occurs at early stages of work (Narbaev and DeMarco 2013).

OVERESTIMATION OF PROGRESS MEASUREMENT BASED IN COST

Figure 7 shows site progress measured in man-hours paid for as compared to EVM measures. EVM measures take into account material and man-hours costs. It might occur that some materials are disproportionally more expensive or cheaper than the others, such that their inclusion in EV potentially distorts real physical progress.

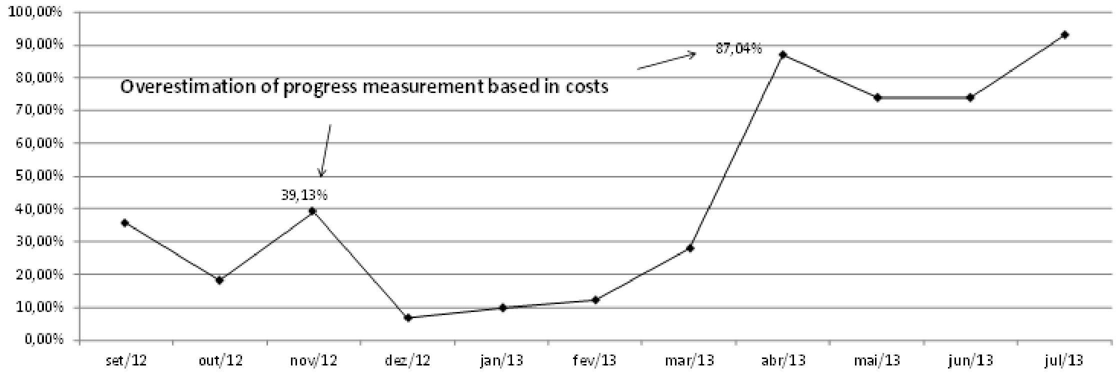

Figure 7: Overestimation of EV progress compared to consumption of man-hours

It can be observed that in April/ 2013, progress measured in terms of costs was greater than the progress measured in man-hour by 87%. Skin glaze facade was being installed in this period, a very expensive stage of work in terms of cost of aluminum frames and special glazing. Thus, a lot of monetary resources were spent in order to achieve a small progress on site in terms of physical deployment of manpower. Alternatively, value at this stage of construction would be better represented by allowing other trades to proceed with their work in a waterproof environment.

MEASURING EV WITH NO DISTINCTION FOR INDIRECT CONSTRUCTION COSTS (IDCC)

Indirect Construction Costs are project expenses incurred by a builder to provide support for operational activities and cater for the provision of general resources they might use collectively (Becker et al. 2012). These costs are connected with activities at business headquarter, site managerial staff, site layout and work supervision. Although indirect costs can generate value, they cannot be used to measure physical progress on site. From a LC viewpoint, aggregation of value accruing from indirect costs might only occur through special activities like quality control, waste reduction, improvement of health and safety at work, learning and documentation of good practices.

Figure 8 shows how much indirect costs inflated measures of direct costs progress on site. Indirect costs were in the region of 20%, that is, a substantial part of EV corresponds to indirect activities that do not necessarily add value according to clients' objectives.

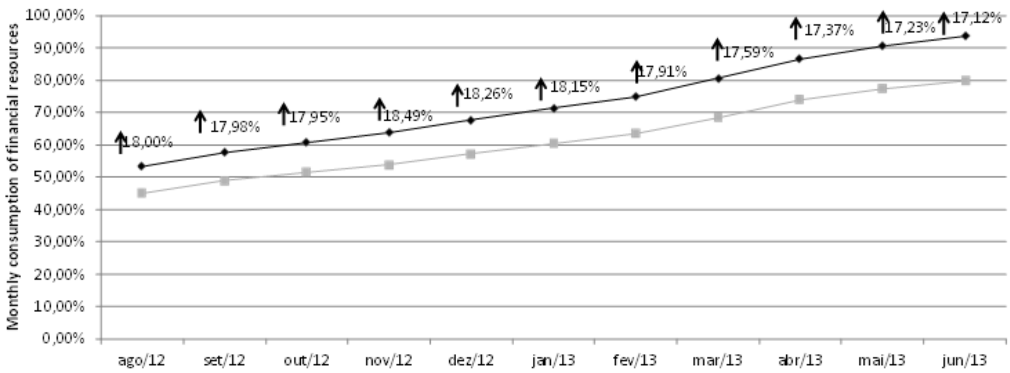

Figure 8: Overestimation of progress measurement considering the indirect costs

CONCLUSIONS

EVM use as a performance measurement technique was demonstrated unsuitable for a typical construction site, according to observations on a building site development in Fortaleza, Brazil. Limitations were discussed in several fields, ranging from vocabulary inadequacy (like the use of word value) to conceptual errors (disregard for the special low progress in the early stages of work).

Forecasting variability was very high, what makes EVM doubtful as a management tool to help decision making. In particular, prediction variability was at its highest at earlier stages or work both in terms of total project cost and duration. Doubtful information might potentially cause an overload on manager's activities, as they try to reschedule work based on alarming forecasts.

The use of costs as parameter for progress measurement was a critical issue. This generated unacceptable levels of distortion of up to 87% as compared to physical progress measured in terms of man-hours.

Finally, the incorrect process of adding indirect cost to monthly progress reports was detected. This generated a 20% increase as related to the actual man-hour progress, what is difficult to justify as EV (Earned Value) for the client.

In short, EVM is restricted to the financial evaluation of progress in a building project, with all shortcomings money produces as a common measure of all things. In order to be valuable, measurement techniques should be grounded on physical and qualitative aspects of production progress. This is a challenge Lean Construction poses to Project Management: performance measurement research way forward potentially is to combine the best characteristics of both management philosophies.

ACKNOWLEDGEMENTS

We would like to thank the CAPES, UFC, UECE for financial support. Finally, we would also like to thank the companies and professionals who participated in this case study.

REFERENCES

Acebes, F., Pajares, J., Galán, J. M., López-Paredes, A. (2013). Beyond Earned Value Management: A Graphical Framework for Integrated Cost, Schedule and Risk Monitoring. Procedia - Social and Behavioral Sciences, 74, 181–189. doi:10.1016/j.sbspro.2013.03.027

Becker, T. C., Jaselskis, E. J., El-Gafy, M., Du, J. (2012). Industry Practice for Estimating, Controlling and Managing Key Indirect Construction Costs at the Project Level. Proceedings of Construction Research Congress 2012: Construction Challenges in a Flat World, West Lafayette, Indiana, US.

Casarotto, R. M., Heineck, L. F. M., Casarotto Filho, N., Castro, J. E. E. (1996) Traçado de curva de agregação padrão para pequenos edifícios em Florianópolis. Proceedings: Scientific Technical Conference on Civil Engineering. Florianópolis, Brazil.

Collis, J., and Hussey. R. (2005). Pesquisa em administração: um guia prático para alunos de graduação e pós-graduação (2nd ed). Porto Alegre: Bookman.

Cooke, J. E. (1980) Charting the Couse of Progress. Building. V. 239, pp.44-45

Creswell, J. W. (2007) Projeto de pesquisa: métodos qualitativo, quantitativo e misto (2nd ed). Porto Alegre: Artmed.

Fleming, Q. W and Koppelman, J. M. (2010). Earned value project management (4th ed). PA, Newton Square: Project Management Institute.

Kim, Y.W. and Ballard, G. (2000) Is the earned-value method an enemy of work flow? Proceedings IGLC 8. Brighton, UK.

Gray, D. E. (2012). Pesquisa no mundo real (2nd ed). Porto Alegre: Penso.

Heineck, L. F. M. (1989). Curvas de agregação de recursos no planejamento e controle de edificações: aplicações a obras e a programas de construção, Federal University of Rio Grando do Sul, Porto Alegre, Technical Report.

Koskela, L. (1992). Application of the new production philosophy to construction, Stanford University, Stanford, CA, CIFE Technical Report 72.

Mattos, A. D. (2010). Planejamento e Controle de Obras. São Paulo: Pini.

Narbaev, T., & De Marco, A. (2013). An Earned Schedule-based regression model to improve cost estimate at completion. International Journal of Project Management. Available at http://dx.doi.org/10.1016/j.ijproman.2013.12.005

PMI (2005). Pratice for earned value management. PA, Newton Square: Project Management Institute.

PMI (2008). PMBOK® Guide (4th ed). PA, Newton Square: Project Management Institute.

Vandevoorde, S., and Vanhoucke, M. (2006). A comparison of different project duration forecasting methods using earned value metrics. International Journal of Project Management, 24(4), 289–302. doi:10.1016/j.ijproman.2005.10.004

White, D. and Fortune, J. (2012). Current practice in Project management – an empirical study. International Journal of Project Managementt. V.20, n.1, p.1-11.

Yin, R. K. (2010). Estudo de caso: planejamento e métodos (4th ed.) Porto Alegre: Bookman.