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LEAN METRIC SYSTEM: PROPOSAL FOR A PERFORMANCE MEASUREMENT SYSTEM FOR CONSTRUCTION PROJECTS

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Abstract: The application of Information Technology (IT) for the constructions management is mentioned as an important success factor. Improved IT management tools can help reduce important issues such as information gathering, misrepresentation, and lack of process standardization. These issues are related to the information flow and transparency, one of the principles of Lean Construction (LC), which will be explored in this research.

This paper aims to present the development of a Performance Measurement System (PMS) with IT application, named Lean Metric (LM). Developed for the application of construction projects, LM uses concepts of hierarchical planning to monitor the constructions term and cost, based on information collected at the construction site.

The LM was developed and tested in the last three years by a consulting company of planning and control of constructions in Fortaleza city. Its creation was crucial to increase the company's competitiveness, reducing operational costs and increasing confidence in the collected data. In addition, indicators are automatically calculated in real time, resulting in transparency in project results.

Keywords: Project Control, Lean Construction, Project Management.

1 INTRODUCTION

In face of the new challenges imposed by the globalized market, the inappropriateness of the Performance Measurement Systems (PMS) used by companies was noticed. This is due these PMSs were based solely on financial accounting (Franco-Santos et al. 2012).

In the construction management area, this was no different. There are several initiatives, at organizational and operational levels, that are well represented by benchmarking clubs around the world (Costa et al. 2004; Horta, Camanho, & Moreida da Costa 2010; Sector 2013) such as: Construction Industry Institute Benchmarking and Metrics (EUA), Key Performance Indicators (UK) and Performance Measurement System for Brazilian Construction Industry (SISIND, Brazil).

Despite these initiatives, Cândido et al. (2016) highlight as the main difficulty the activities operationalization of measurement and control. Other authors point to problems to the operation level, such as overestimation for the supply of materials, undue payments of completed activities, reports preparation, among others (Luu et al. 2008).

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In addition, the information flow is fragmented and erratic, making difficult the management actions that lead to project success. These problems are related to the principles of lean construction: transparency in construction (Koskela 1992), reduction of waste (Ohno 1997) and standardization of control processes (Nakagawa, 2006).

Facing these problem, a consulting company in construction management developed a system to improve its performance measurement process. This system was called Lean Metric (LM) because it was based on the Lean Construction principles.

Thus, a research question arises: how can LM improve the process of performance measuring in lean construction projects? As a premise, the focus control should be in the complete process (Koskela, 1992) instead of the micro control.

Thus, this paper aims to analyze the contributions of the LM to performance measurement process. To accomplish this, it is presents the development, the implementation and test of Lean Metric System as well as its benefits, difficulties of development and implementation and its contributions.

2 Performance Measurement and Lean Construction

Between the period from 1945 to 1990, a paradigm shift in production management occurred with the spread of new management concepts such as Total Quality Management (TQM), Just-in-time, and Lean Thinking (Womack et al. 1990; Spear & Bowen 1999). These concepts came to the construction sector through the 11 principles of Koskela (1992), which later were called Lean Construction by the International Group for Lean Construction (IGLC) in 1993 (Koskela 2004).

Around the same time, in the late 1990s, a variety of quality certifications increased the companies' attention about the creation and implementation of a Performance Measurement System (PMS) (Costa et al. 2004). In general, the performance measurement of construction projects is focused on traditional tripod measures: delivered on time, below or within budget and according to specifications (Toor & Ogunlana 2010). However, performance in LC projects cannot be achieved only with traditional measures (Horman & Kenley 1996).

Projects under lean construction principles aim to maximize value, minimize waste, reduce cycle times (Ballard et al. 2001) and provide production stability improving the construction flow (Sacks et al. 2017). Notwithstanding, as proposed by Cândido et al. (2014), the measurement of performance in lean construction projects should be grounded on physical and qualitative aspects of production progress and not only in financial outcomes. Besides that, improve the information flow it's a critical issue in lean construction (Koskela, 2000). Thus, it is clear the complexity of the performance measurement of lean construction projects (España et al. 2012).

3 Method

This study was carried out under Design Science (DS) methodological approach. The DS approach is eminently focused on solving a practical problem (Collins et al. 2004) and is cited as an opportunity to create and develop a good idea without using the rigor of science (Holmström et al. 2009).

In the IGLC community some articles such as Rocha et al. (2012), Brady et al. (2012) and Brady et al. (2013) support the use of this methodological approach and justify its

application to this research. Thus, seven steps were set for the development of this research (Figure 1).

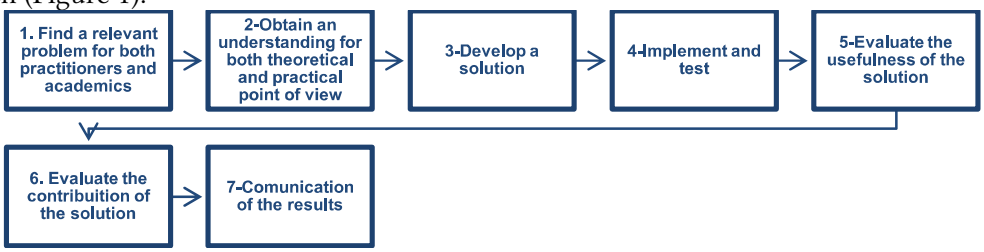

Figure 1: Research process

In following, the results are presented in three parts: 1) development of Lean Metric, corresponding to the steps one to three; 2) implement and test, corresponding to the steps four and five and, 3) evaluate the theoretical contribution of the solution, that cover the steps six and seven.

For the sake of completeness, in the second part (implementation and test), the artefact was evaluated through a case study, as recommended by Hevner et al. (2004). Thus, a secondary methodological approach was applied, the case study (Yin 2010). To collect data for this, semi structured interviews were carried out with managers of consulting companies, who developed and/or used the artefact (Lean Metric).

4 Results

4.1 Development of Lean Metric (LM)

This research was developed within the framework of a construction management consulting firm from Fortaleza, Northeast of Brazil. The company claims the application of lean construction concepts as the main foundations of its consulting practices. To lean principles are added concepts from Theory of Restrictions and good practices of project management, according to the PMI.

The idea of developing the measurement tool was based on the need to standardize the projects measurement and control process. With the expansion of the company, it was found that the field data collection and the consolidation of the results report were very time consuming, making the process more expensive and less competitive.

When it was verified that this problem of improving the performance measurement process was also relevant to the academy, it was decided to develop the Lean Metric while maintaining the theoretical rigor necessary for the application of control tools, according to lean principles.

The first step to develop the Lean Metric was the review of the overall process of Production Planning and Control of the Consulting Company. This process review was based on lean construction, theory of restrictions, project management and performance measurement. As the focus of this paper is the process of control, we present only the results of this step (Figure 2).

The control process is based in the Last Plan System (LPS) (Ballard 2000). The framework of the LPS ensures the integration of the initial (master) planning, the lookahead and the commitment. Complementarily, a Earned Management Analysis (Fleming & Koppelman 2010) was carried out.

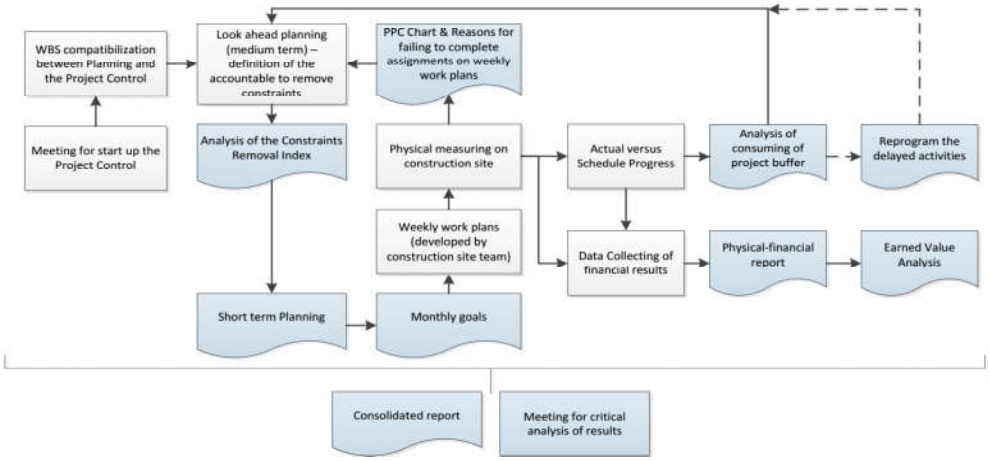

Figure 2: Standartization process of control

First, in the standardization of process of control, the compatibilization between the work break down (WBS) structure (commonly used in PERT planning) with project control is also carried out. The WBS used to budgeting is also compatibilized.

A lookahead planning is carried out to identify the constraints and an accountable is chosen to solve them, shielding the production (Ballard & Howell 1998). A Constraints Removal Index is analyzed as a performance indicator to lookahead planning.

A short-term planning is elaborated considering the status of the production system to generate the monthly goals. So, a weekly work plan is developed in construction site by site staff. The PPC chart and the reasons for the failure to complete the work are analyzed and it becomes an input (feedback) to lookahead planning in the next period of measurement.

At the same period, the physical progress is measured. To make this feasible, all physical measurement criteria were standardized. The criteria adopted were 100% of the work completed, which naturally led to the improvement of service termination.

With the work done and the information from the accounting sector it is possible to calculate the actual cost, which is compared with budgeted cost of the work performed in an earned value analysis. The current progress is compared with planned and the project lung is evaluated to verify the delay tendency, triggering or not the process of replanning.

Finally, plans are drawn up to reverse any distortion with planning. It is at this stage that information is managed and delivered to stakeholders. Through of results presentation, workshops and dashboard at construction site.

4.2 Implement and Test Lean Metric (LM)

For LM implementation, a programming company was contracted to develop a tablet application, used in field data collection. The initial planning and budget of the construction work are inserted in the system so that the activities, durations, dates, costs, labor and measurement criteria are controlled through the LM.

The data collection in the field is done by the clients (staff of construction site) via tablet, and sent to the consulting company from any place with internet access. This ensures the weekly monitoring of the projects, at a reduced operational cost and covering the national territory.

In the tablet application, there is a function with the measurement criteria, in order to standardize data collection, increasing reliability, and resulting in the transparency

improvement. There was an expenditure of time, about 3 hours, after the field measurement for data compilation, but that time was extinguished after using the system.

Through the constraints module, some minutes of meeting with the medium term plans is generated, identifying the constraints that occur in the next three months of the construction work. Moreover, the responsible for its removal and with the deadlines are also registered (Figure 3). In this way, the long term is more integrated and reducing the deviations.

Figure 3: lookahead level of control

LM also has a database with standard constraints. At each new constraint meeting held with clients, if a different constraint occurs, the database is updated. For the measurement of the indicators of constraints removal, automatic emails are sent so that the responsible ones remove them, when they are solved. With this, the Constraints Removal Index (IRR) is generated automatically, which previously required about 45 minutes.

The weekly control - called the short term - is monitored according to the measurements made by clients, in real time, in order to evaluate the Evolution of Weekly Production, Targets, PPC and reasons for the failure to complete the work. Without LM this weekly monitoring could not be done by the consulting firm (Figure 4).

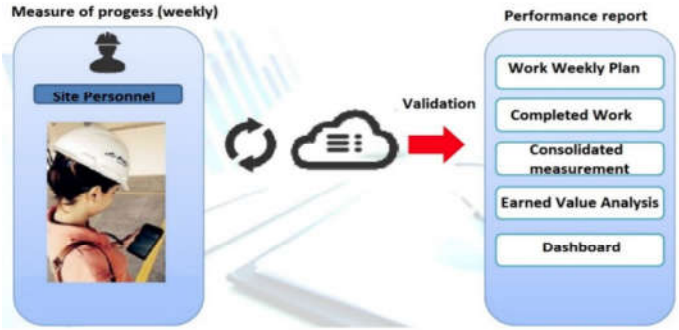

Figure 4: worksite data collection and key issues of performance report

Finally, a ranking of indicators was developed with all the construction works accompanied by the consulting firm, thus generating a benchmarking among the construction works.

During the last three years, the model has been tested and improved in more than 60 construction projects throughout the country, in addition to being used in various types

of construction: Commercial, Residential, Hotels, Malls, Lots, Condos. The improvements achieved with the LM implementation are presented below.

4.3 Improvements with Lean Metric

With the implementation of LM, the following gains occurred:

- Data and indicators are generated in the same planning and budgeting WBS - same packages linked to the short, medium and long term;
- The IRR is generated automatically, which previously demanded about 45 minutes;
- The time for data collection and compilation of all indicators before LM was 44 working hours, being reduced to 24 hours;
- The schedule of purchase of the materials and contracting of services is linked to the physical goals of the construction work;
- For the value-added analysis, after feeding the financial data, as reported by the client, the indicators related to this methodology are generated (Cost Performance Index (IDC), real cost, cost projection, estimate at completion);
- Human errors in the generation of indicators fell in 90%;
- The number of steps that do not add value to the process has been reduced, such as conferences and data manipulation for reporting, in a way that has reduced the operational cost of data collection.

4.4 Lean Metric Contributions

The LM tool showed that it uses the LPS concepts to manage the term and monitor the costs of the construction work, based on the information collected at the site, with more detailed control and reduction of the operational cost in data collection. The contributions of the implementation of the tool are presented in table 1, relating them to the principles of Lean.

Table 1: Lean Construction Concepts x Lean Metric

Principles	For Consultant company	For Customers
Transparency	The automatization of sharing information with customers reduced the doubts in the process of control	Generation of reliable information to improve the decision- making
Reduce the cycle time	Reduction of lead time from data collection to report	Real time performance indicators
Continous improvement	Simple performance and database of information provide continuous improvement of developed tool	The cycle of measurement enables the continous improvement of management actions for construction site along the project time
Standardization	Standardization of process f control Standardization of performance indicators	Standardization of projects performance indicators
Benchmarking	Database of Root cause for failure to complete work	A ranking with all indicators is carried out between different projects for different construction companies

5 CONCLUSIONS

This paper aims to analyze the contributions of the Lean Metric System, an IT tool developed to improving performance measurement process in Lean construction projects. The quality of the system was attested by the number of applications of the tool in different construction works and contexts (61 projects in total).

The first contribution of the system was in the development phase, when it was necessary to standardize the control process, the performance indicators used, the measurement criteria, which made possible to improve the transparency and the continuous improvement of performance measurement process.

It was verified that the simplicity of the LM allows a quick evaluation of the project performance, reducing the time between the information gathering and the decision-making. This provides a twofold benefit: for consulting company and for project manager. By receiving LM reports in a timely manner, managers can change practices to achieve reasonable performance levels.

For the consulting company, there was a reduction of time spent for data collection, reducing delays to producing result report and reducing the client's doubts about the process.

The combination of participatory management, process transparency and the short cycle of control (reduction of control lot and information batch for decision-making) created conditions for continuous improvement for both ways, to performance measurement processes and the project performance.

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