IMPLEMENTING LEAN CONSTRUCTION EFFECTIVELY IN A YEAR IN A CONSTRUCTION PROJECT

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ABSTRACT

It is not easy to change the culture of a company to adopt a different philosophy of production, like Lean Construction. However, through great wish of directors and engineers and the need to manage a large project in the urban area of Fortaleza, Brazil, a plan to implement Lean Construction was developed and implemented. The project includes the construction of 1534 apartments, distributed in 99 blocks, 82 houses, swimming pools and golf fields, totalling an area of 55 hectares, within a planned duration for 10 years.

The main goal of this paper is to present, step by step, all the process of implementation of different lean construction concepts, tools and techniques, and to discuss the benefits achieved in only one year. The construction company had no previous knowledge about lean concepts, and followed specialized consulting and regular classes on the topic during one year. During the study, the engineers started the implementation with the production system design and further the production planning and control using the Last Planner System. It was also developed a project management system in Delphi language which encloses plans for long, medium and short terms, information about availability of crews and control of productivity, safety, quality and customization of the apartments. The system contains real-time information of production control, by the use of tablets to check the services at construction site.

The project achieved a more stable workflow and better matching of labor force and other resources, increased plan reliability, decreased the number of emergency requests for resources and work-in-progress. All supervisors became more involved with scheduling tasks in the operational level and all teams more committed to follow the plan. Currently, the project is running on time and on budget, and the company's director has decided to implement Lean Construction in other projects of the company.

KEYWORDS

Implementation, Lean Construction, PSD, Last Planner System, ICT.

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INTRODUCTION

Lean Construction (LC) can be understood as a new paradigm for project management (Ballard and Howell 2003). Since the 90s, from the pioneer work by Koskela (1992), who adapted ideas from Toyota Production System (Shingo 1989) for the construction industry, many examples of implementation and development of the new paradigm of production management has been presented in IGLC conferences.

The Lean approach is a new way of looking at the wastes that exist throughout the production system and how to reduce or eliminate them to improve the efficiency of the system (Koskela and Dave 2008).

Based on these ideas, an engineer team started the implementation of LC in a large project at Fortaleza, Brazil. The case study started with the development of Production System Design (PSD) (Ballard et al. 2001, Schramm 2004) which is the first managerial task to be performed before a construction project starts. In a Lean system, the production system aim to meet specific goals in terms of maximizing value, minimizing waste, increasing throughput, reducing cycle times, and so on (Ballard et al. 2012).

According to Ohno (1988), the foundation of a production system is the stability, which was achieved in project due to the implementation of Last Planner System (LPS). LPS is well described in the literature as technique for production control that provides a basic stability and create conditions for introducing more advanced lean ideas (Viana et al. 2010).

An information and communication technology (ICT) system was developed to support and control the extensive flow of information about the production planning and control.

This article presents the implementation of several LC concepts and tools implemented along one year in a large residential project to stabilize the production, increase the plans reliability, minimize the effects of variability, and increase the information transparency.

BACKGROUND OF STUDY

DESCRIPTION OF THE COMPANY AND THE PROJECT

Colmeia construction company was founded in 1980 and since then has built more than 100 residential and commercial buildings in prime areas of large cities in Brazil, such as Fortaleza, Manaus, Natal and Campinas, always striving for quality and comfort. The company has Total Quality Program since 1998, and quality certifications such as PBQP H-Level "A" and ISO 9001/2000 since 2004.

The project is a condominium resort located in the city of Aquiraz, Brazil, in an area of 553,545.74 square meters. It began in 2010 and it is expected to take of 10 years to finish. In this period 82 houses and 99 apartment blocks will be built, with 14 apartments each and also an extensive leisure area with swimming pools, barbecues grills, golf courses and sports facilities. Figure 1 presents the perspectives of the project.

Figure 1: Plant of the project and the perspective of an apartment block

LC IMPLEMENTATIONS ALONG ONE YEAR

The project began in January 2011 and until March 2012 no activities related to LC were made. The work on site went through phases of earthmoving and construction of a few blocks of apartments. All the planning was based on a financial distribution determined by the company's board.

In March 2012, the engineer team had the first contact with the LC from basic training on the subject. With the wish to achieve greater control over the large project to be done, the whole team felt the need to absorb the subject. From this moment, trainings on various topics of LC were given by consultants for the site team, consisting of supervisor, engineers, technicians and trainees, with a total staff of 15 people. Overall, in a year, 12 trainings and more than 50 visits to the site were given.

In this case study, lean concepts, tools and techniques, e.g. PSD, LPS, computerized system, visual management, physical flow planning, and so on, were implemented along one year, and they can be seen in the timeline presented in Figure 1, which contains also the next steps for 2013.

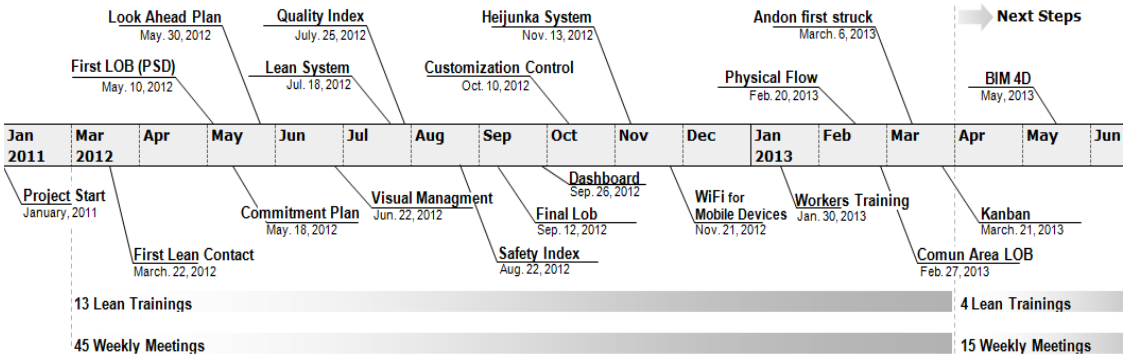

Figure 1: timeline of implementations along the year

All the LC practices implemented in the project passed through the following steps:

1. Lean Training: monthly lessons about PSD, LPS, TFV (Transformation, Flow and Value generate), Toyota House, *kanban*, *Heijunka*, *andon*, just-in-time, continuous flow, pull production, wastes, and others, were taught by consultants;
2. Recognition of a real problem: based on LC concepts training, the engineer team was able to identify problems in the production system and develop possible

solutions. Besides the trainings, weekly visits were made by the consultants to the site in order to monitor the implementation and propose new ideas;

3. Development and Implementation of solutions: the various tools implemented were discussed among all members of the engineering team and consultants, who became aware about the operation of the tools in the construction site;
4. Control and Standardization: after the implementation, the tools were controlled by the team through some performance indicators, and, in some cases, improvements were made to stabilize the workflow. Then, a new lean tool was standardized in the production system and other lean ideas were pursued.

IMPLEMENTATION OF LEAN CONSTRUCTION

APRIL, MAY AND JUNE 2012

The main activities and tools to develop the PSD were based on Schramm (2004). The scope of decisions concerned, mainly, in definition of execution strategy, sequence of activities execution in pavement, and the study of workflows according to the capability of production resources.

For the study of workflow, from May 2012, a Line of Balance (LOB) was developed for the first three services of the construction. By September of the same year, the LOB went through modifications and additions of services to be finalized. The LOB of the leisure areas was developed almost one year later, in the end of February 2013.

The Last Planner System was implemented at the same time that LOB was being developed. During four months, the foresight and commitment plans were made in MSExcel spreadsheets. In the planning meetings, the consultants were present to help the team of engineers to conduct the meetings and extract performance indicators.

Visual Management was implemented by placing the LOB in the administration's office and in the worker's cafeteria. In the administration's office are also exposed the medium and short term plans and leading indicators. It was also implemented a magnetic board of the site with the inventories local, boardrooms and subcontractors, bathrooms and water drinkers, and exhibition of activities in execution or finalized.

All the implemented practices along this phase are presented in Table 1.

Table 1: Implemented Lean Practices

Lean Practice	Decisions	Implemented tool and practice
Production System Design	Definition of execution sequence	Network of precedence relationships among activities
	Study of workflows	Line of balance of the block of apartments
	Definition of execution strategy	Line of balance of the project (long term plan)
	Defining the capability of production resources	Spreadsheet of capability of production resources
Last Planner System	Look ahead planning	12 weeks planning List of Constraints

		IRR (Index of Removal Constraints) IRRfp (Index of Removal Constraints late)
	Commitment planning	Weekly Work Plan Weekly planning meeting Causes for non-compliance Percent Plan Complete (PPC) Percent Plan Complete with Quality (PPCQ) Percent Plan Complete with Safety (PPCS)
Visual Management	Location of temporary facilities on construction site	Magnetic Board of construction site
	Transparency of information about team performance	Board in site office with PPC
	Transparency of information from plans	Line of Balance and Look ahead plan on site

The main products from this phase are shown in the following Figure 2: Line of Balance and magnetic board that shows the exhibition of the entire project's LOB and the commitment planning meeting with the entire team, and the application of visual management on site.

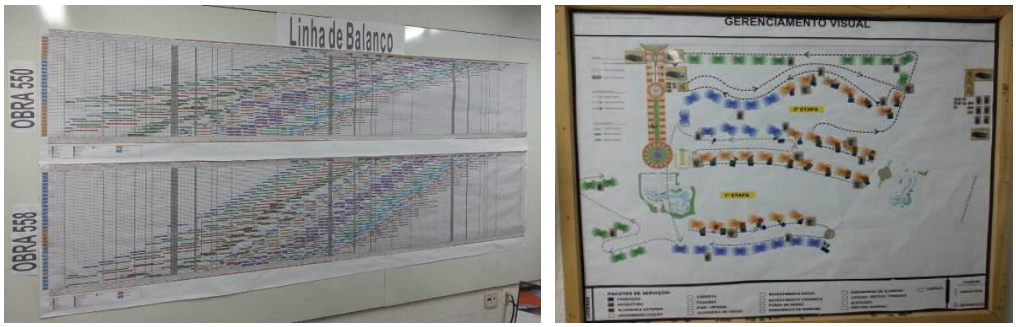

Figure 2: Line of Balance and magnetic board

JULY, AUGUST AND SEPTEMBER 2012

Due to the length of the project and the growing number of on-site activities, there was a need to develop a computerized system capable of providing more agility and security to exchange information.

So, in July, a computerized system was developed in Delphi with the attempt to integrate in a database the information from short, medium and long terms. The system was called "LEAN" to identify the concepts it contains, as well as the positive changes that were occurring in the project because of the change in production philosophy. Then, all MsExcel spreadsheets used before were abandoned.

The engineer team began to use the system to plan and control all services, crews and machines. Thus, indicators of quality and safety also became controlled on the system and updated at the end of each service.

In September, a dashboard was created in the system, and then all indicators were monitored in real time by the engineer team. Consequently, it is possible to view several indicators, in friendly screens, since the beginning of lean implementation,

such as PPC, quality and safety, as well: idle teams, team productivity, causes of non-compliance activities, among others (Figure 3).

The performance of the crews, from the company and subcontractors, is shown on televisions in the administration room and in the cafeteria, to have transparency of information and to encourage continuous improvement (Figure 4).

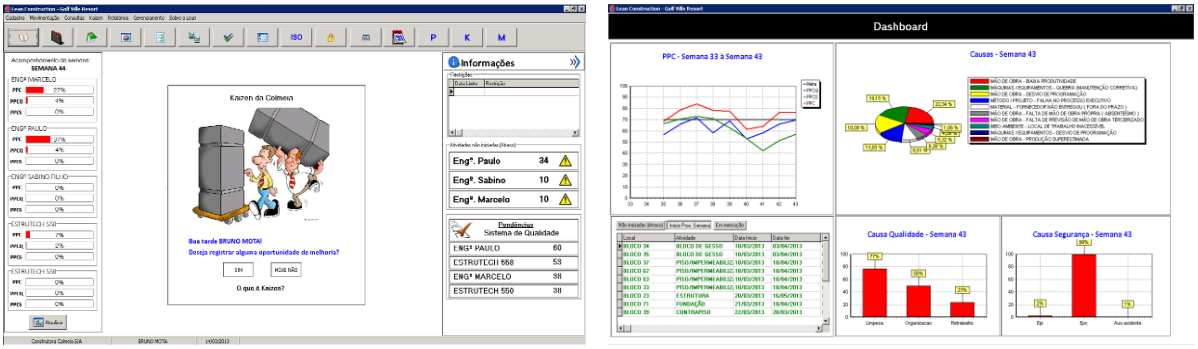

Figure 3: Main screen of "LEAN" System and Production Dashboard

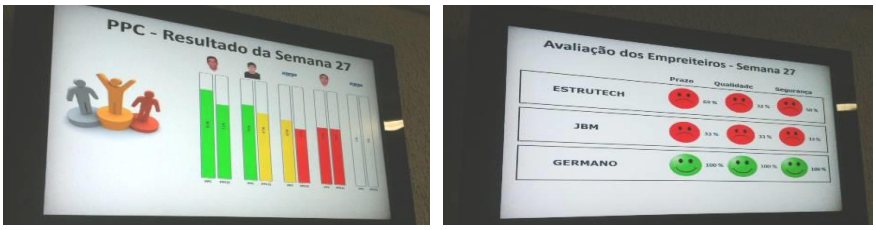

Figure 4: Visual Management on TV screens

The apartment customization has always been a concern of the team since it has been causing some problems in other sites of the company. That's why it became planned and controlled in the "LEAN". All dates for execution of each service were passed on to the company's customization sector who had a plan for dealing with clients and avoid the services to stop due to the lack of definition of specifications or materials.

OCTOBER, NOVEMBER AND DECEMBER 2012

In November 2012, due to the scope of work and the high number of services running at the same time, there was a need to ensure accuracy in the measurement of indicators of all services on site. For that, the control of services started to be done by mobile devices on site, and the data were sent directly to the system database via wi-fi (Figure 5).

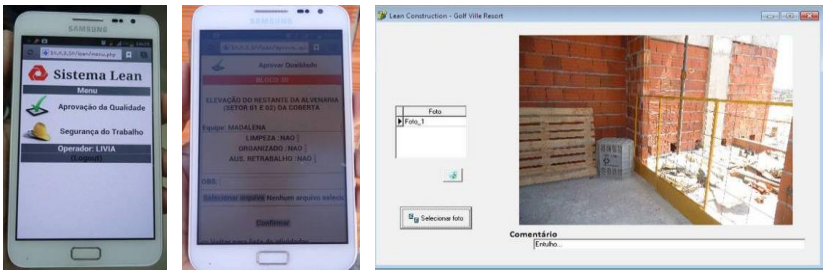

Figure 5: mobile devices for controlling quality and safety on site

Also in November 2012, due to the great movement of the machines in the construction site and to organize the site and increase the productivity of crews, it was developed a *Heijunka* system. This system consists of tablets placed on machines, that from a daily program of activities put the tasks in a priority order, warns the operator about the block and activity in which should go and do. If no task is assigned to the operator, an audible alert is emitted in the administration's office, working as an *andon* warning that there is a resource waiting (a machine) at the site. The first alarm rang in March 2013. With this system established, the machine usage was balanced. But, for any unforeseen circumstances, the workers have *Kanban* cards to request any missing material (Figure 6).

Figure 6: Tablet in a telescopic forklift, jobsite supplied and material *kanban*

JANUARY, FEBRUARY AND MARCH 2013

In January 2013 the workers also participated in a training to assimilate the new method of work. To encourage the use of new techniques and increase productivity, workers were noticed about a prize for the best average among the leading indicators: PPC, PPCQ and PPCS in every 3 months (Figure 7). Those prizes are not in cash, but in utensils and domestic devices that may be useful in their homes.

Figure 7: Best performance crew award

Due to the large site extent and large materials handling, it was important the determination of inventories places. Several studies were done about physical flows, and with the help of the workers, the engineer team planned the physical flow of the site, in which were stipulated storage locations for materials, for example. Figure 8 shows the difference in the organization of the site before and after the studies.

before

after

Figure 8: Before and after defining inventory areas on site

DISCUSSION OF THE RESULTS

PERCEIVED IMPROVEMENTS

One of the biggest improvements perceived, with no doubt, is the implementation of Lean concepts in the project. Since the beginning of the construction was without any form of planning, it can be stated, after one year, that there was an integration in the management of production, quality, safety and customization. Thus, increased the control of services, resulting in more reliability of internal and external customers regarding the project final outcome.

With all the numbers available to the team in a single database, and with the possibility of fast analysis, there was more interaction between employees, which began to expose their needs and solutions to work problems. With the needs of the field acknowledge, the engineers could formalize the activities, relating tasks to each workday. And, through visual management information, it increased transparency and reliability in the work. Increased transparency also helped the relationship with contractors, who now have more dedication and commitment in activities to improve their production indicators.

With the necessary information in real time, the computerized system improved decision making by the engineering team. Since the system has various interfaces, it can be accessed on site and through remote access, enabling the monitoring of all project activities and data analysis for various sectors of the company.

Some indicators were collected to verify the results achieved with the implementation of Lean Concepts and tools used. The PPCs, PPCQ and the PPCS had a very low average and a large variation on the beginning. Now, it's running between 70 and 80% and with a tendency to go higher (Figure 9).

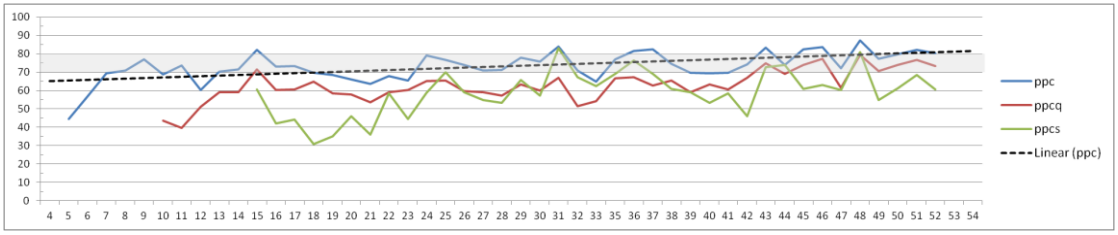

Figure 9: PPC, PPCQ and PPCS indicators.

The productivity also increased during the project, especially after the implementation of the *Heijunka* and *Kanban* tools. Figure 10 shows the crews productivity average for brickwork, starting from 10m²/men/day and reaching 16.5m²/men/day. The rhythm deviation it's also checked every week for all activities. Figure 10 shows the graphic for the brickwork task. In the detail, the executed is reaching the planned.

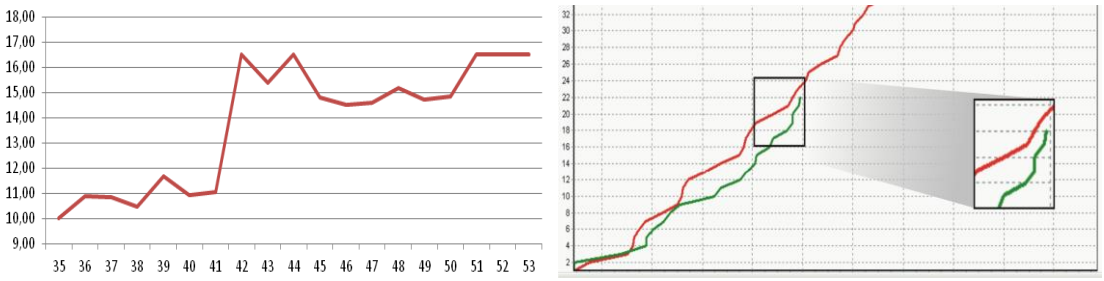

Figure 10: Productivity of brickwork and deviation of rhythm of production.

DIFFICULTIES DURING IMPLEMENTATION

The greatest difficulty for the implementation of LC concepts was to promote understanding to field employees, such as foramen and crew leaders. It was difficult the understanding of the new philosophy of planning and production, as well as the importance of complying with the program that they helped draft.

The fact that the LC concepts were implemented with the construction in progress, collaborated with this difficulty. Thus, the rate of introduction of new tools was restricted to the onsite activities and the difficulties inherent of a large project.

Also, there were some difficulty about the control of the daily work that was previously done by spreadsheets previously known, and came to be through a computerized system with new controls, routines and access areas.

NEXT STEPS

The next step is to implement BIM 4D, and do studies on physical flows and future plans of attack. Other stages of the project will be released soon and the site will have a constant movement.

Another step is to increase the acts about environmental sustainability. Given the long duration of the project, the implementation of sustainable attitudes are necessary.

Also, maintaining what took place for a year, routines and tools already implemented always go through processes of continuous improvement and will continue to be used in the work. The company wants to increase the use of LC in other projects, and is planning upcoming implementations in the near future.

CONCLUSIONS

The paper presented the beginning of a Lean journey of a large-sized company in Fortaleza, Brazil. During the project, the site team and consultants decided to implement different initiatives based on Lean concepts and understood the project dynamics from different points of view.

The tools used provided managers and workers with more information, simultaneously available to all of them, in a manner that they have never had in any of the company's projects. The initiatives increased productivity, reliability, transparency and control in all tasks.

Thus, several project indicators reflect the positive results obtained with the implementation of Lean Construction concepts and tools, in only one year of great effort.

The authors shared the experience they gained, in one year, while following the changes so that other companies, regardless of their size, can also be motivated to achieve gains through the implementation of Lean concepts and tools.

ACKNOWLEDGMENTS

The authors thank directors of the construction company for the opportunity to develop the work, and to project team for the effort in the Lean implementations with SIPPRO consultant's partnership.

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