IMPLEMENTING LEAN CONSTRUCTION CONCEPTS IN A RESIDENTIAL PROJECT

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ABSTRACT

The main goals of this paper are to present a case in which Lean Construction concepts were implemented and to discuss the benefits achieved during the process. The case study was developed during the construction phase of a residential project in the urban area of Fortaleza, Brazil. The project comprised the construction of 18 houses financed by a private investor and it was constructed and managed by a small-sized construction company. After lean concepts were implemented the project achieved a more stable flow of work and the number of emergency requests for resources decreased dramatically. Also, the project was completed a month in advance when compared to its original schedule thus allowing the investor to sell the units sooner than expected. Finally, after analyzing the benefits achieved in this pilot project the company's upper management has decided to use Lean concepts in other projects, and the private investor wants to make sure Lean is used in other projects financed by his company. The paper aims at contributing to the literature on Lean Construction on the industry papers section by presenting a success story experienced by a small-sized construction company.

KEY WORDS

Production system design, transparency, line-of-balance, home building

INTRODUCTION

The main goals of this paper are to present a case in which Lean Construction concepts were implemented and to discuss the benefits achieved during the process. The case study was developed during the construction phase of a home building project in the urban area of Fortaleza, Brazil. Based on guidelines provided in previous IGLC papers (e.g., Alves and Formoso 2000, Ballard 2001), the authors worked alongside the project manager, the foreman, and the company's owner to re-schedule the project and plan its main work and material flows. Special attention was given to papers on production system design, tools and principles used to provide transparency to work flows and enhance communication between managers and workers at construction sites (Alves and Formoso 2000; Schramm et al. 2004).

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LITERATURE REVIEW

The production system design represents one of the first managerial tasks to be performed before a construction project starts. Through the design of a production system, engineers aim at reducing variability, improving predictability, and improving the flow of work by aligning multiple interests so that value is delivered to internal and external clients (Ballard et al. 2001). The goal is to design a system that is capable of delivering value with minimal waste through better alignment of goals, definition of assignments, and management of flows.

According to Ohno (1988), the foundation of a production system is the stability that supports other activities of the system. Stability is one of the basic tenets of a Lean system and it is the foundation of the Toyota Production System which provides the support to the system's two columns, namely just-in-time and *jidoka*. In the construction literature, Ballard and Howell (1998) suggest that in order to achieve stability it is necessary to shield production against variations and undesired effects from interaction with suppliers, among crews, and with the various flows of resources and information necessary to deliver a construction project. Once the system is shielded and stable, managers can evaluate the system's actual capacity and test how much of that capacity can be used to deliver the project.

The main goals of a Lean system are to deliver the best quality, at the lowest cost and the shortest lead time to its clients; therefore, the entire system should be designed to achieve these goals. Amongst the Lean concepts that support these goals transparency, e.g., visual management, is one of the most important ones as it allows the system to communicate with its workers and managers thus enhancing their ability to detect problems and correct them before they halt the system's flows (Koskela 1992). For that reason, every effort should be made to enhance a system's ability to communicate with managers and workers. Santos (1999) provides several examples of the application of transparency and visual management in construction. It is worth noting that the initiatives related to visual management are usually inexpensive and provide a good basis to communicate decisions related to a production system design and its indicators (Alves and Formoso 2000).

Schramm et al. (2004) suggest a series of interactive tasks that should be carried out to design a production system for housing projects. Initially, a base unit (e.g., a house) should be defined so that the base unit installation sequence and the necessary capacity to build it can be set. Parallel to that, a study of workflows should be done for the base unit. The next step is to define the project execution strategy, i.e., the sequencing of processes and their paths at the construction site, and how this definition impacts the work carried out at the base unit level. Finally, the capability of resources necessary to complete the project is defined and a study of the project critical tasks is carried out. According to Schramm et al. (2004, p.11), once the production system design is set, it is important to have ways to communicate the adopted strategies and definitions to managers and crews, and "*there must be an emphasis on process transparency in terms of dissemination of plans and goals.*"

CASE STUDY

The study presented in this paper was carried out in a project that comprised the construction of 18 houses financed by a private investor. The project was constructed and managed by a small-sized construction company based in the city of Fortaleza in north-eastern Brazil. During the study, the project managers implemented different lean construction concepts, tools, and techniques aiming at organizing the construction company's production planning and control system. Managers also worked on the design of the project's production system following the guidelines suggested by Schramm et al.'s (2004) model for production system design.

The company decided to embark in a lean journey after the crews had almost finished the first of the 18 houses in the complex. The project had started at house number 09, in the front part of the complex, so that this house could serve as a model to be presented to potential customers and serve as a first run study (Ballard et al. 2001) for the management to evaluate actual productivity rates at the site. The project duration had been estimated in 10 months according to the experience of a company director. After the first house was finished, and the initial productivity rates were analyzed, the project managers realized that the entire complex could be executed in 8 months. The original estimates were far off the mark as the duration indicated in the contract had too much slack in it.

DEFINITION OF THE SEQUENCE AND STRATEGY OF EXECUTION

Before the implementation of Lean concepts and tools, the company did not have any standard procedure regarding the planning and control of its projects. All the decisions were made based on the company director's and long-time collaborators' (last planners) experience. Thus, the first step in the study was to carefully define the sequence and strategy of execution for the remainder 17 houses (Figure 1), and to define the capacity available for the project.

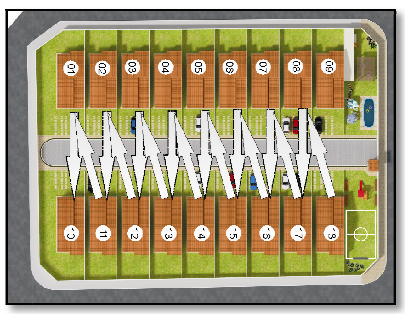

Figure 1: Construction site plan and sequence of execution

ANALYSIS OF THE WORK FLOW

Activity work flows were analyzed based on the production rates defined in the previous stage and a base unit for all the tasks was set as a house. Once a trade started working in a house it should proceed with its work until the last house was finished. The line of balance (LOB) was the tool used to represent the long-term planning of the project because of its ability to communicate important concepts such as continuity, pace of work, as well as information related to activity durations, interferences between trades, and trade location. The LOB was developed using MS Excel®. In order to assure a continuous flow of work and maintain the stability of workflows, the managers analyzed the project suppliers' lead times and defined milestones for the acquisition of materials. Also, all materials necessary to complete a service used to be delivered to work stations before the beginning of work shifts.

The managers separated internal and external set-up times by separating the work that could be done before crews arrived at each work station.

COMMUNICATION OF PLANS, GOALS, AND INCENTIVES

A set of tools was used to improve the communication of the plans and goals to the last planner and his crews, as well as to the investor and the company's managers. Along these lines, an agenda with a bill of resources needed for construction was created to indicate when each of them had to be quoted and ordered so that they would be delivered before activities planned starting dates. The procurement system developed in MS Excel® alerted the buyer about the need to start the purchasing process and it acted like a *kanban* system pulling materials when needed according to the plan represented in the LOB. Also, the LOB set the pace, path, and the sequence of work and these information was displayed to workers in the form of A4 cards in front of each house. The cards indicated the work that had to be done in each house by a specific team in a period of time, the starting date, and the due date. The cards worked like *kanbans* which pulled the work necessary to complete each house for each phase of the project.

It is worth noting that this project had a longer timeline than what was achieved by its end. Reaching a shorter schedule was not only a matter of shaving some time off the schedule by re-programming activities through the LOB, but also a matter of engaging workers to work in a faster pace than they used to. Thus, the management decided to design an incentive system for workers to commit to and follow what was defined by the LOB. For each half day saved, the worker received coupons to participate on a raffle with different prizes at the end of the project.

DISCUSSION OF THE RESULTS

After lean concepts were implemented the project achieved a more stable flow of work and the number of emergency requests for resources decreased dramatically. The project was completed a month in advance and allowed the investor to recover his investment sooner than expected. Besides the qualitative data collected for this project, hard numbers were also collected to prove the efficiency of the new concepts and tools used by the company.

After the company owner decided to implement Lean concepts and tools, the project management team revised the project duration once more. The new duration (7 months) represented a decrease of 12,5% in time when compared to the duration achieved for the first house (8 months). Table 1 shows a comparison of average daily productivities for the main activities necessary to complete one base unit (one house). The productivities indicated for 8-month duration (column C) were collected from the execution of the first house whereas the productivity rates indicated for 7-month duration (column D) were obtained after the other 17 houses were completed according to what was defined by the LOB. The improvement in productivity (column E) observed for the activities presented in table 1 represents an average of 15.7%.

Other indicators were collected to compare and contrast the status of the project with other projects built by the company. The managers wanted to verify the results achieved with the implementation of Lean concepts and tools used.

Table 1: Productivity improvement for selected activities

Activities (A)	Unit (B)	Productivities 8 months (C)	Productivities 7 months (D)	Improvement in productivity (E)
Excavation	m3 / man / day	13.13	15.00	14.2%
Mansonry (rocks)	m3 / man / dia	3.85	4.50	16.9%
Mansory (bricks, course)	m2 / man / day	8.47	10.00	18.1%
Slab (assembly)	m2 / man / day	15.09	17.50	16.0%
Structural concrete (25 Mpa)	m3 / man / day	4.38	5.00	14.2%
Mansory (bricks, bull stretcher)	m2 / man / day	10.50	12.00	14.3%
Plastering 1 (chapisco)	m2 / man / day	71.63	82.00	14.5%
Plastering 2 (reboco)	m2 / man / day	13.78	16.00	16.1%
Plastering 3 (emboço)	m2 / man / day	12.64	15.00	18.7%
Finishings	m2 / man / day	10.56	12.00	13.6%
Painting	m2 / man / day	16.33	19.00	16.4%

A list with the main indicators is presented:

- About 85% of the tasks were initiated at the planned time, whereas the other 15% started late due to supplier delays (doors and windows) and the painting activity (due to rain).
- About 15% of the activities were completed as planned. About 80% of them were finished before their due date.
- Before the procurement system was implemented, workers often stopped because they lacked materials to complete the planned activities. About 10% of the bids and requests for material purchase were delayed or had wrong information in them. The percentage of late/wrong requests was reduced to close to zero after the procurement system was implemented. This helped the achievement of a continuous flow on site because materials were delivered according to what was needed and at the time they were necessary.
- Managers noticed that the productivity rates turned out to be better than originally planned, in the beginning of the project, because the last planner had underestimated productivity rates to protect workers. As the managers realized this fact, they adjusted the line of balance and set activities' pace according to actual productivities verified on site. After the line of balance was adjusted, the productivity rates kept going up revealing that workers were motivated by the goals set and the incentives they would get to meet the deadlines.

CONCLUSIONS

The paper presented the beginning of a Lean journey of a small-sized company in Fortaleza/Brazil. The authors shared the experience they gained 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. However, it is worth noting that the results achieved are limited by the conditions present in the case study, i.e., project's favorable cash flow, incentives given to early completion of tasks, high level of repetitiveness, use of actual productivity vs. planned to re-schedule the project.

During the project, the company decided to implement different initiatives based on Lean concepts and understood the project dynamics from a different point of view. The project managers and the investor realized the importance of shielding production against variation, and organized the procurement and scheduling systems, and the physical flows on site as a means to reduce non-value added activities. The tools used provided managers and workers with more information, simultaneously available to all of them, than they had ever had in any of the company's projects. The initiatives increased productivity (an average of 15%) and reduced the project duration (from 8 to 7 months). An incentive system was put in place to motivate workers to achieve the goals set by the project managers, and it succeeded as workers responded to the challenges dictated by the schedule. Several project indicators reflect the positive results obtained with the implementation of Lean Construction concepts and tools.

Currently, the company is refining its procurement system, training the management team on Lean concepts and tools, and trying to innovate by creating new ways to put Lean into practice.

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