

Application of lean manufacturing in construction management

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Abstract

The construction industry in recent decades has been facing internal and external pressures, such as financial crisis, industry competitiveness and increased importance of quality required by the client. Because it is a sector, which has a low level of productivity, and high levels of waste, both with materials such as with labor, it is necessary to search for new management practices and production control. The development of a productive environment which aims to reduce waste, costs and deadlines, meeting customer needs and increasing efficiency and productivity in construction sites, made the application of the concepts of Lean Manufacturing in Civil works broke old paradigms in this area. In this way, this work has as objective the study of the implementation of Lean Manufacturing and its effect on the construction management, through the development of case studies on construction sites, where these concepts were

applied and the results obtained are exposed in this work.

Keywords: Construction; production management; lean manufacturing;

1. Introduction

The construction industry is going through major changes, which are affecting directly the economy of the countries, increasing competition and the demand for quality and, thus, requiring that methods, concepts and technologies be adapted from the manufacturing to the construction site [1].

Presently, tools that allow high competitiveness levels and the identification of recurring problematic characteristics, productive and managerial, are imperative. The search for and alternative that is cheaper, time efficient, require less raw material and manpower, is eliminating unnecessary practices, which sometimes can lead to failures in a construction site. The Lean Manufacturing/Construction System is largely used to increase productivity and quality levels.

A significant aspect of the construction industry is its heterogeneous form, which is comprised of a wide range of services and technologies, servicing different demands [2].

Studies conducted in different countries assessed the need for planning, pointing that the main cause of the low productivity levels of the construction industry are strongly related to deficiencies in planning and control [1].

Inside that context, it is suggested that companies from the construction industry develop the knowledge about the Lean Construction System and the tools used by that system.

The work's objective is to develop guidelines for the implementation tools that assist the application of Lean Manufacturing, approaching the construction planning and control using technical observation and research. Three different building companies were observed and adopted, in collective, the practices, seeking the improvement on management, planning and control of the construction sites.

2. Materials and methods

2.1 Lean construction

Lean Construction is defined as a management model for the production in the construction industry, based on the Lean Manufacturing method, which had the objective do increase efficiency levels in the production [3].

The Lean Construction method is the Lean Manufacturing method applied in a construction site, enabling the identification of activities which can cause the interruption in the workflow [4]. Those activities cause waste and rework and, therefore, should be minimized.

Project management in the construction industry based on the Lean system is different from the conventional practices once the result is a set of clearly defined objectives for the delivery process, project performance increase, simultaneous conception of products and procedures and production control during project's lifetime [5]. Therefore, developed the concept of Lean Construction, establishing eleven principles of the application in civil construction, being those listed below [6].

1) Reduce the fraction of activities with no effect on the result – in order for the process to improved, the losses must be reduced, which will increase the conversion and workflow efficiency [7].

- 2) Take client’s needs in consideration in order to increase the value of the product – internal and external client’s needs should be considered in the planning and production management [8].
- 3) Variability reduction – production processes are not totally stable, having specific needs for resources (time, workforce and raw materials), even if the final product is the same [6].
- 4) Cycle time reduction – the set of all periods linked to materials, essential to a construction. Reducing the cycle time denotes that every process is provisioned in the right time, avoiding big stocks formation [9].
- 5) Simplify via steps, parts and links reduction – a process simplification can be achieved via the readjustment of its useful steps or parts and the elimination of useless tasks. The tools used in order to achieve the process simplification are such as the use of prefabricated elements, multidisciplinary team, and application of 5S’s style tools, efficient process planning and others [10].
- 6) Flexibility increase in the results – it is the increase of the capacity of modification of the final product, according to the client needs, without significant cost increase [10].
- 7) Increase process transparency – the more transparent a process is, the easier to have better control and improvements. Transparency decreases the probability of failures, increase general production visibility and foster improvements [11].
- 8) Focus on global process control – the segmented process control has its transcurent workflow via different units or across the organization [12].
- 9) Introduction of continual process improvement – the continual process improvement reduce losses, increasing the product value. It is an internal process, with strong participation of employees, which should receive capacitation, alongside other initiatives, leading to the constant process improvement [12].
- 10) Workflow balance via improvement in conversion – in order for production improvement to happen, workflows and conversion should be prioritized since in each production step, different features must be observed. Generally, the more complex a step is, the more residues are generated inherently, giving space to more improvement via workflow modification [6].
- 11) Benchmarking – it is the practice of application of methods and processes used by successful companies. It is a simple practice, which is less investment intensive. It reduces competitiveness, creating a pattern of methods and processes between companies from the same economy sector [9].

The Figure 1 below, refers to the conventional model, in which only the assembly flow is explicitly considered, having influences of Fordism.

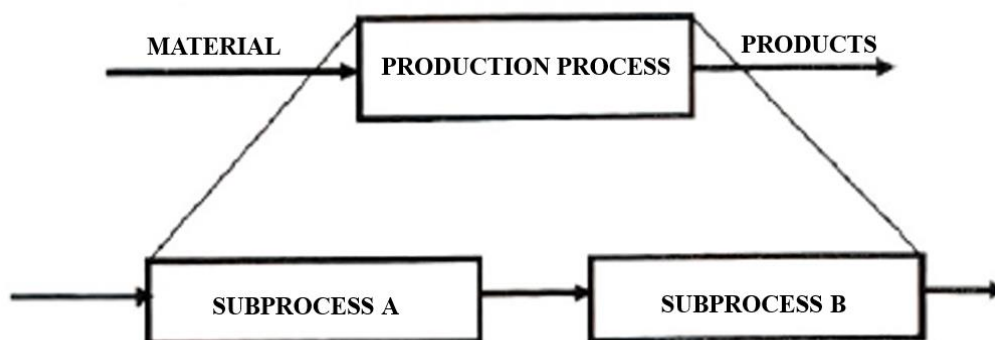


Figure 1. conventional process model.

In the Lean Construction Model, Figure 2 below, the assembly flow and other physical flows are explicitly considered: the materials flow, information and work. Even though those flows do not create value to the construction itself, they are a significant portion of costs and workforce.

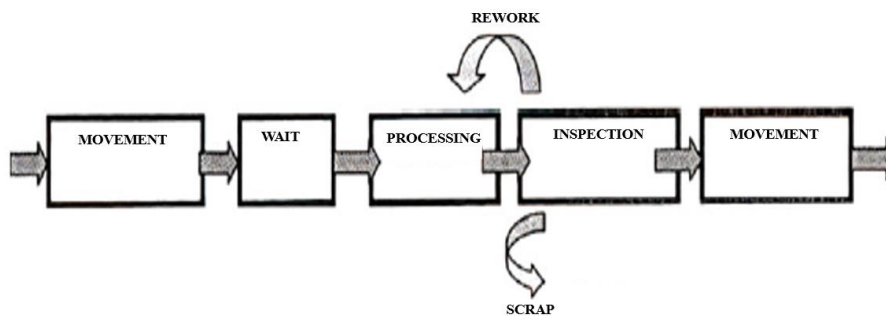


Figure 2. lean construction process model.

2.2 Field research

The field research was conducted with three different building companies, in order to assess the implementation of the model to the reality of the construction industry. Employees, construction and quality managers were interviewed so a vision of the problems and restrictions specific to each company could be better assessed.

The field research followed the steps below:

- 1) Informal conversation;
- 2) Informal interviews;
- 3) Questionnaire;
- 4) Periodic technical visits;

The first step consisted of informal conversation with the company employees, individually. During these conversations, the employees were asked about the conduction on the construction, how they learned their profession and if they felt capable of performing the same role in a different way.

The second step consisted in exposing the Lean Construction method and answering employees' questions about the concepts of each of the eleven principles of the method, illustrating how those principles could be applied in the construction site. After the method was exposed, an informal interview was conducted with employees and managers. The questions asked can be find below:

- 1) Did you already know or heard about the Lean Construction method before?
- 2) Would you accept the implementation of the principles here in the construction site?

After the interview, the third step began via the implementation of the method, using the eleven principles. The fourth step consisted on the inspection of the application of the tool via periodic visits of the construction site.

After the construction was completed, the site manager repeated the questionnaire of the eleven principles, in which we can verify the results of the implementation of the method and the improvements achieved.

The workflow of the procedure is illustrated in Figure 3, below.

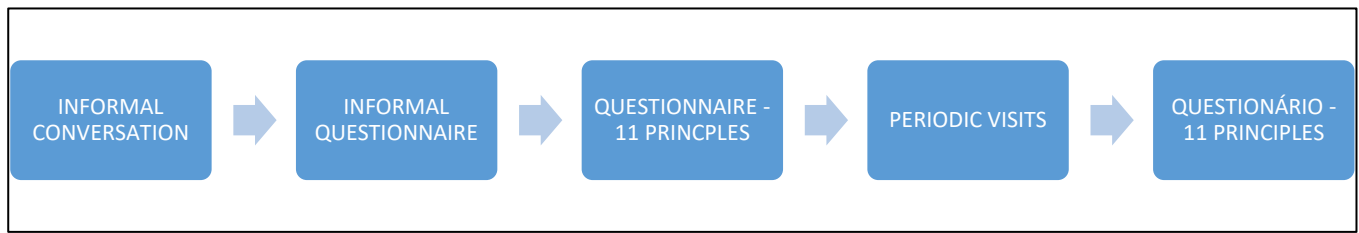


Figure 3. workflow of the procedure.

The used questionnaire is similar to the one in Table 1, based on the eleven principles, and with the objective to search for the root causes of the everyday problems in the construction site.

Table 1. Board of questions of the eleven principles.

Principles	Questions and aAnswers
1-Reduce activities that do not add value.	Are building materials discharged near your place of application?
	Is there a planning of the activities that will be carried out at the construction site by the operators?
	Does the company have equipment that assists in the movement of materials?
2-Increase the value of the product by considering the needs of the customers.	Is there a customer needs program, getting all the data regarding the potential requirements and preferences?
	Is there a periodic check of the services applying quality management?
	When completing the work is a customer satisfaction survey done?
3- Reduce variability.	Is there a labor training with the workers?
	When starting an activity, is there a sequence of tasks defined and the necessary resources made available?
	Are the procedures performed standardized?
4-Reduce cycle time.	Does the company work with small teams?
	Do the employees avoid a lot of movement and wait during the activities?
5-Simplify to decrease the number of steps and / or parts.	Are there precast elements used for execution to reduce the number of steps in constructing a building element?
	Is there a training matrix?
6-Increase flexibility in product execution.	Is there a possibility of plant flexibility?
	Is there a form for the modification projects?
7-Increase transparency.	Does the company employ control with performance indicators?
	Are there any strategies to improve the organization and cleaning of the work? Which?
8-Focus control throughout the process.	Is there a long, medium and short term planning?
	Does the company work with reduced inventories and partial delivery of materials?
9-Establish continuous improvement.	Are there meetings held with the team to solve problems and propose improvements?
	Does the company rewards employees with the best results?
10-Balance the improvements of the flows with the improvements of the conversions.	Are the processes used rationalized, and the material and handling losses are reduced?
	Does the company look for technological innovations that fit its work?
11- Brand Benchmarking	Does the developer seek and identify other successful techniques in other companies, making visits or gathering information from these processes?
	The good practice adapted to the reality of the construction company is ?

After the application of the questionnaire, an action plan began:

- Meetings room (a specific place was chosen so the meetings would not interfere in the daily activities).
- Chart with Lean Construction 11 principles (a chart with the principles was made based in the results obtained in the questionnaire. This way, the auditor could record the audit results in a visible manner for all the employees).
- Daily audits (daily audits were performed by the foreman and the engineer and the results were registered in the chart with the 11 principles).

Daily meetings before the start of activities (daily meetings were conducted in order to assess the previous day results and to discuss improvement opportunities).

1. When exposing the method and conducting the informal interview with the managers and employees, only the managers stated that they had already heard of the method of “Lean Construction” but did not yet

know it, since all agreed to start applying the principles in the work.

2. The first analysis carried out with the workers of the three builders was done through the informal dialogues, in which the questionnaire of the 11 principles of Lean Manufacturing / Construction was applied. These questionnaires were answered with answers varying between yes and no, to transform the questions into statistical data, the average of the positive answers of the questionnaire was adopted (adopting one for yes and zero for no), where it was answered by all the workers who worked in the construction site of both constructors, thus enabling the evaluation of the conditions prior to the qualification.

3. The following graph, illustrated by Figure 4 represents the percentage of employee responses for each of the questions asked in the applied questionnaire:

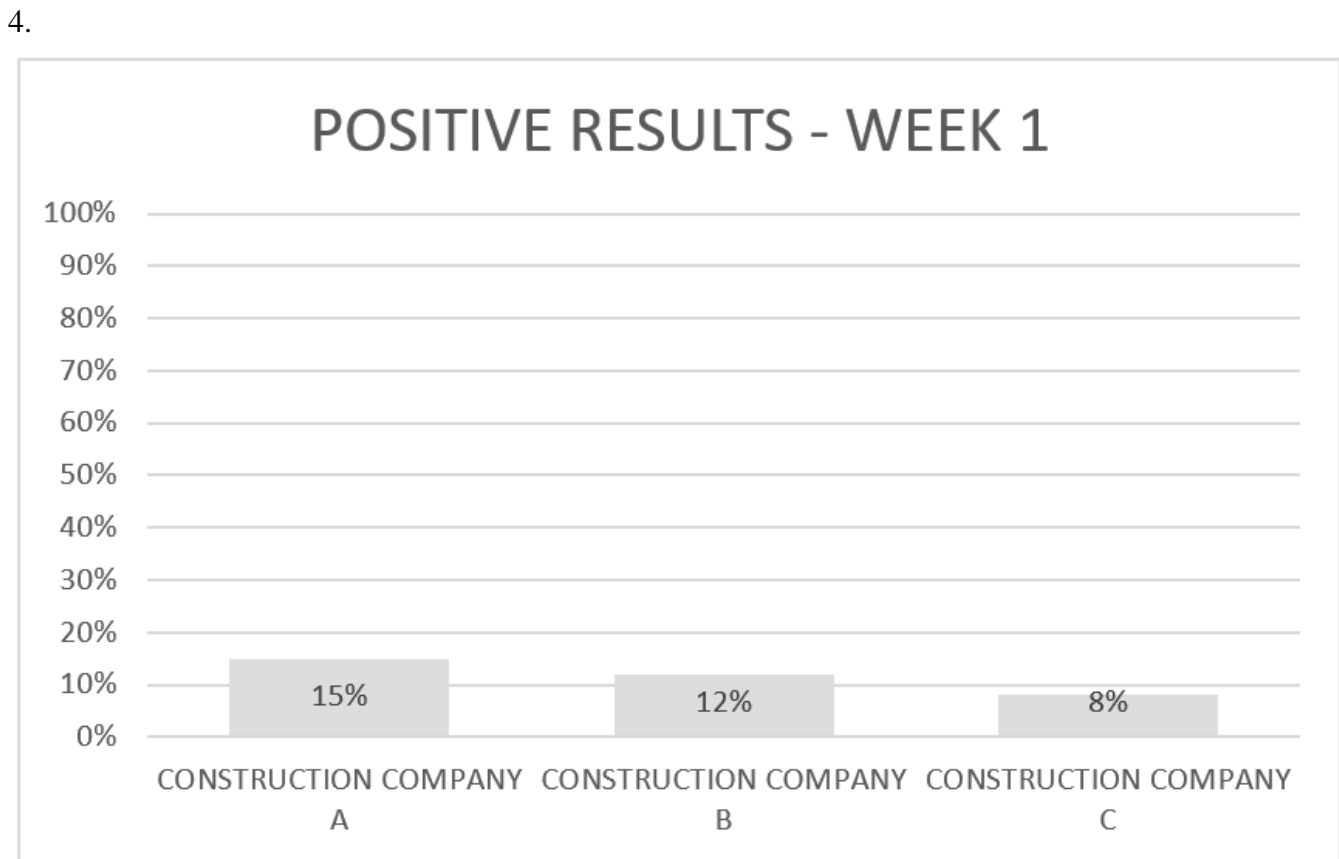


Figure 4. search result.

5. It was identified that, for the most part, employees have cultural problems, such as low schooling and lack of training. They revealed that they learned the trade only from observing it without any theoretical or practical scientific basis. In addition, they have shown that they have no intention of learning another way to perform the function they perform, by causing discomfort in learning new ways of working that were already accustomed.

6. Capacity building based on the 11 principles of Lean Manufacturing / Construction, including meetings and daily audits, was begun in the following weeks to keep the tool active and potentiated, so the results gradually evolved for both building companies, Figure 5.

7.

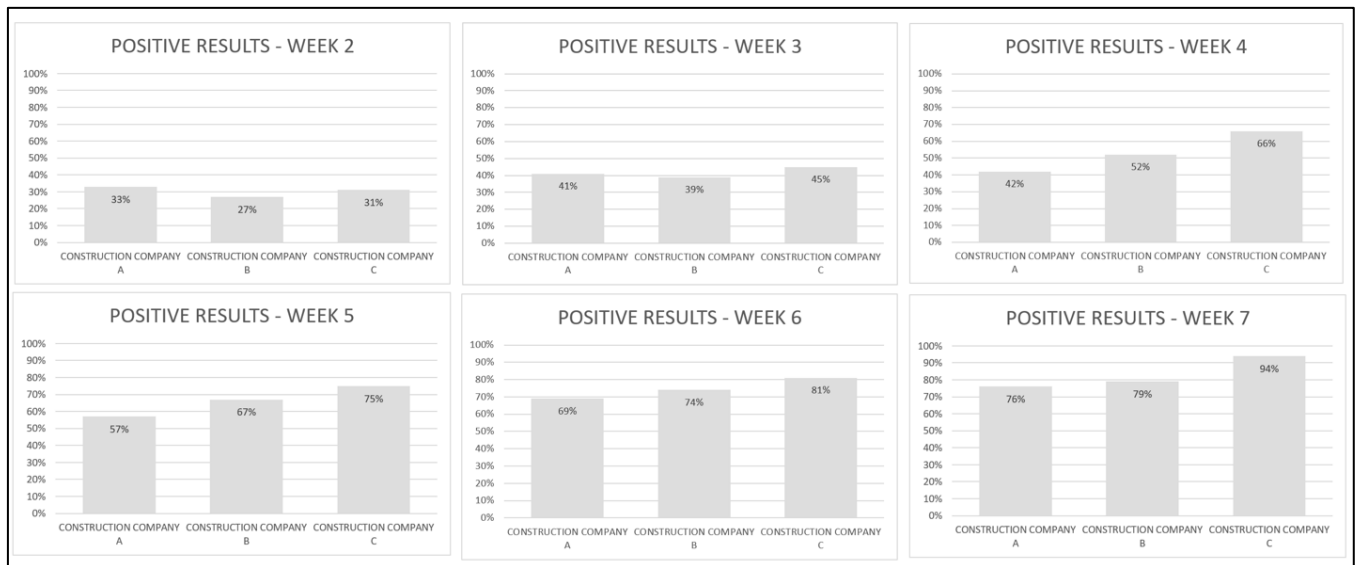


Figure 5. search result.

8. The mentioned improvements will represent a 9% in cost reduction for company A, 5% for company B and 7% for company C if the method is kept until the conclusion of the construction.
9. The cost reduction is mainly due to the process loss and variability reduction, which could require rework in the future. As a result, the company competitiveness increases and, thus, better prices are available for the final clients once the service’s quality is improved due to the employees’ better qualification.

3. Conclusion

The study of the Lean Construction method, the application of the questionnaire and the periodic visits, clearly showed improvements when comparing to the initial situation. As planned, it was possible to minimize cultural resistance and to introduce new values to the daily life of the construction site and in the employees’ lives, since they started to become interested in professional improvement.

Lean and Industry 4.0 must be integrated and aligned. Once united, all of these powerful paradigms will help streamline processes, increase efficiency, and business and customer values. With the most reliable and relevant information and figures available at the customer and supplier interfaces, Lean's current practices can be improved, which, in addition to cutting costs, generate real profitable growth. At the same time, these processes make it easier for 4.0 Industry technologies to arrive faster and deliver greater benefits. However, this all increases the need for those interested in innovations to invest more in training, in the training of their own team, to become able to use the tools.

Lastly, it can be concluded that the changes were welcomed, and with the necessary adaptations, the Lean Construction method brought only positives results and ensured the construction success.

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