Contemporary Engineering Sciences, Vol. 11, 2018, no. 68, 3385 - 3395
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2018.87354

Incidence of the Lean Philosophy Construction in the Productivity and Analysis of Processes in Internal Finishes in Masonry Living Quarters in the Construction Projects: Case-Residential Complex Callejas-Cucuta-Colombia

Oswaldo Hurtado Figueroa[1], Javier Cardenas Gutierrez[2] and Carlos Acevedo Peñaloza [3]

[1] National Learning Service
SENA- C.I.E.S, Cucuta, Colombia

[2] Civil Engineering Program, Engineering Faculty,
Universidad Francisco de Paula Santander, Colombia

[3] Mechanical Engineering Program, Engineering Faculty
Universidad Francisco de Paula Santander, Colombia

Abstract

The technical supervision in the construction projects is of special importance for the correct execution of the activities, its objective is to reduce the errors that are incurred when carrying out the processes inherent to its development. The finishes, as a final stage in the construction of homes, generate visual appeal to customers by encouraging their option of purchase. However, the costs contemplated in this stage are important in the budget. Defining an efficient work method helps improve the completion time of the activity by promoting compliance with the schedule stipulated for the project, together with the improvement of profitability for the contractor. The present work applies some tools

of the Lean Construction philosophy of the two methods implemented in the application of the coating and detailing or final finishing for houses built in masonry, through continuous observation, using the balance sheet tools, the Last Planner system with the weekly schedule and lines of balance for the programming of activities. From these measurements, time-operator relationships were obtained, which sought to identify productive, contributory and non-contributory activities that affect productivity in the development of the project, reaching conclusions that maximize productivity, reducing activities that do not generate value to the Project.

Keywords: Constructions, Masonry, Materials

1 Introduction

The search for perfection by reducing losses and increasing profitability in engineering projects is nowadays the priority of companies in the sector at the global level, companies that with the help and implementation of innovative processes aim to significantly reduce the existing gap between construction waste and profits. Implementation of lean construction largely relies on organizational learning and knowledge creation, which is in turn promoted by lean techniques. However, there are few studies in knowledge management of lean construction [1]. The constant innovation together with the continuous improvement become reference axes for the connection and permanence of the companies in the competitive market. That is why, for example, the evolution of knowledge of the physical phenomena has found when modeling a strong tool to interpret its real behavior [2]. This continuous innovation requires a well-planned system of knowledge management that enables the firm to excel in technological, market, and administrative knowledge creation [3]. The construction industry, in addition to the values that characterize them as a profitable activity for investment, adds to the progress processes in which the different commercial areas are immersed, keeping in progress technological developments that sustain the two objectives that it has in place, as goals to give a new focus on production and customer service, which are identified as the reduction of waste in materials and work times and the maximization of value for customers. Lean construction is one of the new philosophies that has been implemented by Toyota in their development process, which now applies to the construction industry in order to smoothen the construction project and increase the contractor's profit by eliminating waste [4].

The changes established by the company, in favor of its general improvement, must be assumed by all the personnel that are part of it, from the management to the operational staff, the ideas provided, before their application will be subject to effectiveness criteria and relevance by selecting those that meet the requirements for their assessment. These calls for change did not merely request the adoption of new technology and tools, or the acquisition of the new skills needed to operate them. Rather, they called for a change in the way the industry fundamentally operates

and invariably focuses on the management of the entire construction process [5] Ideas must adapt appropriately to the variability of local conditions in order to make them reach the individual who, without pressure, must understand the importance of change avoiding reactions of rejection or disagreements when taking orders, this is because people need to clearly understand the reasons why the way they do things need to change; otherwise, they will generate resistance [6]. The Lean methodology based on the improvement of manufacturing processes whose purpose is the elimination of waste and activities that do not generate value to the process and therefore the final product, allows immediate reach in the goals of productivity, competitiveness and profitability of the companies that apply it (less waste = + value). Its implementation in the processes and activities related to civil engineering works have been seen with good eyes thanks to the results obtained through the application of its fundamental principles such as, elimination of the process wastes, effective management of the value stream, maintaining a continuous and reliable flow of the production and process elements, pull-based project planning and control, just-in-time delivery of materials and components instilling a continuous improvement culture [7].

Lean construction (LC) promises outstanding results in managing the construction process and achieving the project's goals by eliminating waste. In the case of Sustainable Construction (SC), systematic training and research are crucial to provide proper interaction and collaboration with the stakeholders, thus enhancing the quality of life for the future construction industry [8]. The process of implementation of the Lean Construction philosophy in the city of Cúcuta, began five years ago and has brought with it the implementation of tools and methodology, where the processes of construction of the structures and finishes of the buildings are optimized, achieving to identify and reduce waste or loss in the various activities that make up the construction projects. The present investigative work evidences the results obtained by applying the tools of the Lean Construction philosophy in the real estate project Callejas Reservado executed in the City of Cúcuta - Colombia executed by the construction company Promotora Callejas del Este S.A.S.

2 Methodology

The D block was taken as a study sample, made up of 8 houses of two floors contemplated in the reserved residential project Callejas Reserved by the construction company Promotora Callejas del Este S.A.S located in the city of Cúcuta-Colombia. The contractor used two methods for the execution of the coating activities and the detailing or finishing of the internal walls of the living quarters, from which the costs, material and labor yields were analyzed, using the Balance Sheet tool, through visual inspection, in periods of 10 minutes, and field measurements of the processes and activities related to the coating and detailed or internal finishes of homes built in masonry. For the monitoring and control of the programming of the activities, the Lean methodology of balance lines and the support

of the weekly programming of the Last Planner system were used. To carry out the different analyzes, whose results were compared generating data and conclusions in order to improve the productivity of the work by means of the selection of the defined work method supported in the cost and productivity analyzes, the goal is to build the project while maximizing value, minimizing waste, and pursuing perfection [9]. It is important to note that today more attention is paid to the interpretation of the results of the tests in terms of service performance, as well as giving reliable indications of the capacity of the material to perform certain types of duties [10]. Each construction project is varied and is carried out in diverse conditions, deriving in different factors that influence positively or negatively in the yields and consumptions of manpower, which can be grouped under seven categories [11].

Table 1. Factors that affect performance or labor consumption

Number	Factor
1	General Economy
2	Labor Aspects
3	Climate
4	Activity
5	Equipment
6	Supervision
7	Worker

Source: Estimator's general construction man-hour manual, John S. Page. Adaptation of the Engineers Antonio Cano R y Gustavo Duque V

For the identification of the comparative factors in the yields identified in each of the methods implemented by the contractor for the development of the activities inherent to the processes that were carried out in the application of plasters and finishes in the living quarters, it was taken into account the factors indicated in table 1.

The productivity in the activities, is another important factor that in addition to depend on the 7 factors indicated in table 1, requires of the labor efficiency of the group of workers that execute the activity, work measurable by the executed man hours.

The classification of labor efficiency presented in table 2 generated the starting point for carrying out the analysis of the activities carried out by the team or executing team, to which the method implemented for carrying out the work was studied. The tasks next to the execution times.

Table 2. Classification of the efficiency in the productivity of the workforce

Efficiency in productivity	Range
very low	10% - 40%
low	41% - 60%
Normal (average)	61% - 80%
Very good	81% - 90%
Excellent	91% - 100%

Source: Estimator´s general construction man-hour manual, John S. Page.

The development of working methods manages to determine the productive status of a specific task, helps reduce activities that are not necessary during a process and allows to complete a task in less time of operation. Studies on work methods are carried out on activities that tend to be repetitive, control and measurements of different kinds of performance indicators are vital in order to determine if performance is improving [12]. For which, in the beginning, it was applied in a greater way in the manufacturing sector, later its benefits were made known and it was possible to adapt to the other economic sectors, however, the procedures to study a specific work method are the same in any productive sector. In practice, a set of tools need to be adopted in construction projects to achieve a higher level performance, through which learning and knowledge creation are unintentionally initiated and supported [1]. The metrics in the development of work activities are of essential importance for the productivity of companies along with compliance of the stipulated timetables. The determination of work time is an important consideration for specialists in the study of work. Any calculation of production must be made with due regard to the duration of the operations and their execution time [13].

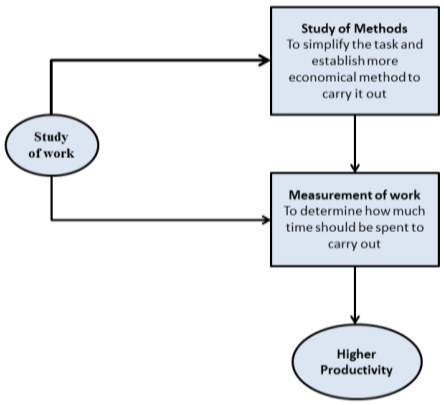

Figure 1. Study of work
Source: (international labour organization (ILO), 1996, p. 20)

The development of the project was guided through descriptive, explanatory, correlational, qualitative and quantitative research, due to the obtaining of data

through direct observation and continuous measurement of work in the field, in order to identify the factors that did not support the productivity of work methods, through the analysis and identification of the delays presented, in the stipulated times for the execution of the coating and detailed activities or wall finishes. With the implementation of balance sheet field formats with which the follow-up of the visual inspections carried of the executed activities were carried out, along with the control of inventories through the management of the Kardex, information was collected on the entry and exit of the materials and their stored amounts. The Microsoft Project program and the balance sheet methodology were used to obtain the crews and the execution times budgeted for the development of the contemplated activities. The analysis of the statistical data with their respective graphs was made with the help of the SPSS software.

2.1 Methods implemented by the freelance worker

The analyzed activities include the coating and the detailing or finishing of the internal walls of the houses, processes that contemplate the application of stucco-pañete and plastic paste with white finish. The contractor presented two procedures for carrying out these activities, methods that were the object of study in the present investigative work, their difference lies in the disparate application of materials and the number of people per crew, characteristics that ultimately affect the general work and estimated finish time.

Table 3. Differences between work methods for Coating

Method 1	Method 2
Application of a stucco-pañete layer	Application of two layers of stucco-pañete
The material is stored in storage and consumed according to the daily progress.	The material is supplied according to the progress of the crews.
Three employees for the execution of the activity.	Four employees for the execution of the activity.
Less consumption of stucco-pañete.	Greater consumption of stucco-pañete.
Folding easel type scaffolding.	Tubular scaffolding with scissors.

Table 4. Differences between working methods for Detailing or Finishing

Method 1	Method 2
Two employees for the execution of the activity.	Two employees for the execution of the activity.
Application of a layer of plastic paste and paint.	Application of a layer of plastic paste and paint.

The taking of time for the execution of each one of the activities in the respective implemented method was prioritized, in this way the data of interest that was obtained was compared through descriptive graphs.

3 Results

The values presented as results were the consolidation of the data recorded in the different formats, which were then processed using the methodology described specifying the conditions of each of the stages for the two processes analyzed, in the methods used in the coating application and detailed or finished. In terms of materials, their average consumption Kg/m^2 was analyzed between the two methods.

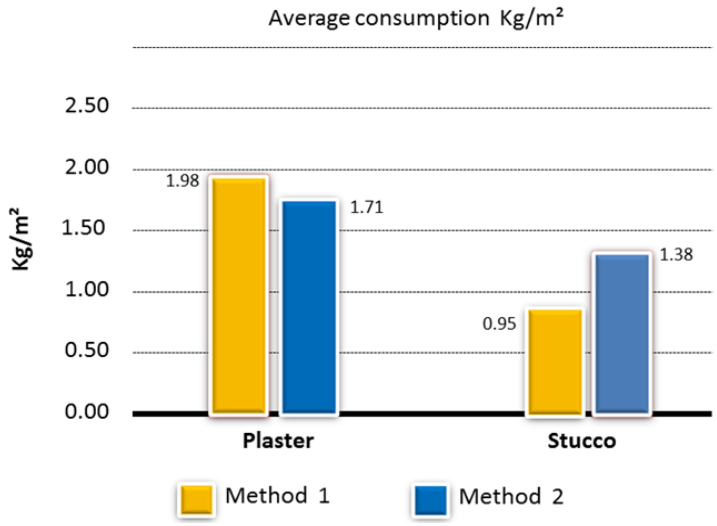

Figure 2. Average consumption materials

The output in m^2 / day of labor is consolidated with the general data collected. For the analysis, the work crews used for each of the implemented methods were taken into account. The crews are made up of the 1 x 0 ratio, where 1 equals the number of construction officers and 0 refers to the number of assistants or workers needed to carry out the activity.

The graph above represents the performance of the workforce in unit of m2 / day workforce, also establishes that the method No.2, worked with four work forces whereas the method No.1 only worked with two, these work forces were distributed throughout the living quarters analyzed.

The days executed were compared with each of the methods used, having as a comparative guide the time stipulated in the initial budget.

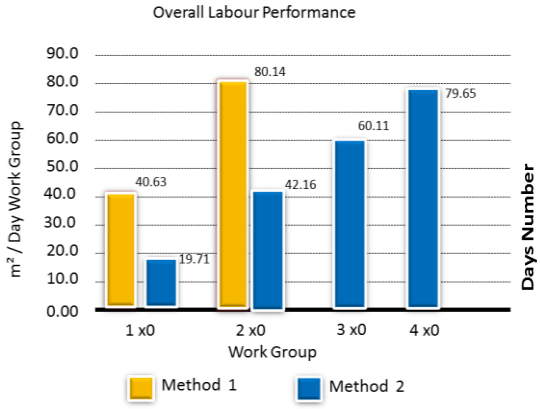

Figure 3. General Labor Data

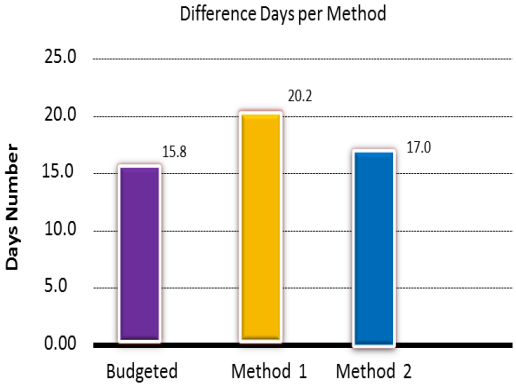

Figure 4. Comparison of days executed

Productivity in a general way for the activities in the two methods:

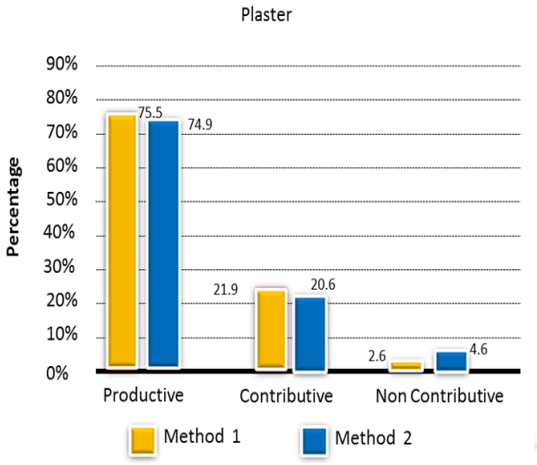

Figure 5. Productivity Plaster

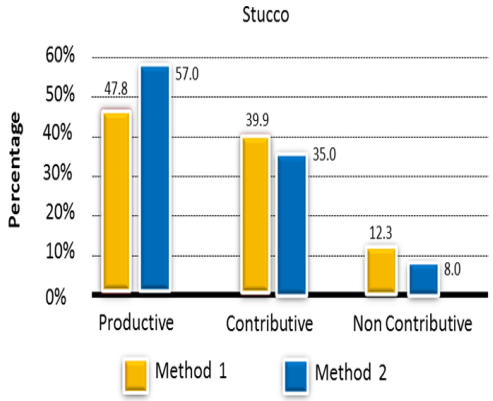

Figure 6. Productivity Stucco

4 Conclusions

It is concluded that the performance in execution of the workforce depends on the application of layers of the materials and of the available tools and equipment to fulfill the task at hand. The tools and equipment of the crew determined their performance. The improvement in the output during the phase of the wall and plate cladding in work method No.2, improved the replacement of the scaffolding of scissors, advantages that were evidenced in the transport of equipment with greater ease, safety with platforms, notable improvement in the orderliness and cleanliness of the workplace, reduction of bad worker postures, greater reach of workers in high areas, a situation that considerably reduced the non-contributory time of the operating personnel.

The use of innovative tools and equipment for mixing processes simplifies the work of the operator, a situation that allows a significant increase in the contributory times due to the speed with which the mixtures used are prepared, a task that decreases in time and avoids interruption in the execution caused by the lack of prepared material or waste due to excess. For the method of work No.1 in the activity of coatings of walls and plates there were identified levels of productive activities superior to 70%, with development in contributive activities of 21.9%, which represent, that in a period of observation of ten minutes I can identify a worker who loses about two minutes in support activities such as transportation, cleaning, preparation of mixtures, among others.

The productive times for work method No.2 are greater than seventy percent (70%), which at the level of general productivity of work is good, this means that seven out of ten minutes are employed in activities that are really productive and that promote the transformation and progress of the project. In terms of support activities and non-contributory activities, they represent the remaining thirty percent (30%), that is, at least 3 out of every ten minutes the activities could be contributing or not, to the final product.

The activities categorized as productive represent certain equality in the identified methods, however, a difference can be seen between support activities and non-contributory activities, among which it can be established that there is evidently a small impact in terms of preparation, placement and transportation of the material. The method of work No.1 was highlighted, that on average eight out of ten minutes (80%) analyzed were observed productive or transformation activities that generate increase in value to the final product. The remaining two minutes (20%) of the time are spent on support and non-contributory activities, among which the transport of scaffolding, benches, cleaning and cleaning, preparation of the material among others is untied.

The implementation of the tools and methodologies of the Lean Construction Philosophy, have had a great contribution and incidence in the productivity and quality in the construction projects of civil works in Cucuta, since they allow to make a better way to take information, perform more accurate diagnoses, analyze the information collected, which allow us to take future actions to minimize non-contributory activities and waste materials, time and quality of projects.

Lean construction aims to maximize the use of materials and labor of construction, and avoid any waste and non value-added activities. Recently, lean construction has been successfully implementing in the construction industry for waste reduction (both building material waste and schedule delays) and to improve project performance (increase customer satisfaction, practice planning, and safety hazards prevention) [14].

References

[1] L. Zhang, X. Chen Role of Lean Tools in Supporting Knowledge Creation and Performance in Lean Construction. *Procedia Eng.*, **145** (2016), 1267–1274. https://doi.org/10.1016/j.proeng.2016.04.163

[2] M. Coba, C. Acevedo, J. Navas, Validation of a Non-conservative Mechanical Model Applied to the Low Energy Impact Phenomenon, *Contemporary Engineering Sciences*, **11** (2018), no. 53, 2631-2639. https://doi.org/10.12988/ces.2018.86275

[3] S. Popadiuk, C.W. Choo, Innovation and knowledge creation: How are these concepts related?, *Int. J. Inf. Manage.*, **26** (2006), no. 4, 302–312. https://doi.org/10.1016/j.ijinfomgt.2006.03.011

[4] O. Abdelnaser, A. Abdulsalam, Barriers to prioritizing lean construction Incidence of the Lean Philosophy Construction, *Acta The. Corviniensis, - Bulletin of Engineering*, **8** (2015), 53.

[5] C. T. Da, C. Milberg, K.D. Walsh, Exploring lean construction practice, research, and education, *Eng. Constr. Archit. Manag.*, **19** (2012), no. 5, 512–525. https://doi.org/10.1108/09699981211259595

[6] G. Shang, L. Sui Pheng, Barriers to lean implementation in the construction industry in China, *J. Technol. Manag. in China*, **9** (2014), no. 2, 155–173. https://doi.org/10.1108/jtmc-12-2013-0043

[7] A. Tezel, L. Koskela, Z. Aziz, Current condition and future directions for lean construction in highways projects: A small and medium-sized enterprises (SMEs) perspective, *Int. J. Proj. Manag.*, **36** (2018), no. 2, 267–26. https://doi.org/10.1016/j.ijproman.2017.10.004

[8] M.A. Marhani, A. Jaapar, N.A.A. Bari, M. Zawawi, Sustainability Through Lean Construction Approach: A Literature Review, *Procedia – Soc. Behav. Sci.*, 101 (2013), 90–99. https://doi.org/10.1016/j.sbspro.2013.07.182

[9] E. Peralta, F. Sorzano, M. Coba, C.Acevedo, G. Valencia, Experimental Study of the Cutting Processes on the Microstructure of an ASTM A36 Steel, *Contemporary Engineering Sciences*, **11** (2018), no. 47, 2333-2340. https://doi.org/10.12988/ces.2018.85238

[10] R. Al-Aomar, A lean construction framework with Six Sigma rating, *Int. J. Lean Six Sigma*, **3** (2012), no. 4, 299–314. https://doi.org/10.1108/20401461211284761

[11] L.F. Botero, Análisis de Rendimientos y consumos de mano de obra en actividades de construcción, *Rev. Univ EAFIT*, (2002), 9–22. http://www.redalyc.org/pdf/215/21512802.pdf

[12] P. Erik Eriksson, Improving construction supply chain collaboration and performance: a lean construction pilot Project, *Supply Chain Manag.: An Int. J.*, **15** (2010), no. 5, 394–403. https://doi.org/10.1108/13598541011068323

[13] G. Kanawaty (con la dirección de). *Introducción al Estudio del Trabajo*, cuarta. G. anawaty (con la dirección de), editor. Ginebra; 1996.

[14] S. Li, X. Wu, Y. Zhou, X. Liu, A study on the evaluation of implementation level of lean construction in two Chinese firms, *Renew Sustain Energy Rev*., **71** (2017), 846–851. https://doi.org/10.1016/j.rser.2016.12.112

Received: August 11, 2018; Published: August 30, 2018