Contemporary Engineering Sciences, Vol. 11, 2018, no. 100, 4957 - 4964
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https://doi.org/10.12988/ces.2018.810544

Application of LEAN Tool "Line Balancing" to Determine the Productivity of Workforce in Activities of Plastering and Internal Detailing in Two-Story Houses Made of Masonry

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Abstract

The finishing work of construction represents an aggregated value that makes the difference when a client is deciding to buy a house. The stipulated costs for plastering and detail activities for houses, in occasions, surpasses 30% of the total value of the construction work, considerable costs that require constant control and supervision both in the analysis and the execution of the construction. The implementation of the LEAN philosophy in this activity is not commonly implemented due to the lack of knowledge of the tools that this method provides. This research shows the implementation of line balancing, as a LEAN tool, in the plastering and detailing activities for two-story masonry houses, constructed in the housing project Callejas del Este which took place in the city of Cucuta, Colombia. The implementation of this tool contemplated the analysis of execution times of the work crew, the results were synthesized in tables for better interpretation and conclusions of interest were developed for the improvement of the observed processes and activities.

Keywords: Lean Tools, Masonry, Productivity

1 Introduction

In the development process of a construction project, the elaboration of the budget and the work program play a fundamental role since they anticipatedly establish the cost and the duration of the construction and are indispensable to determine the viability of the project [1]. For this reason, office tools that help perform the analysis and considerations must be applied to processes and activities inherent to the various tasks for the execution and posterior advance of the constructive project, maintaining an effective control of the construction.
Over the last decade, when the competitive environment suffered an important transformation due to globalization, business organizations have intensified their search for strategies that give them a sustainable competitive advantage [2]. The construction of buildings is not aloof to these changes since it puts into practice sustainable alternatives based on the use of methodologies and tools that reduce construction waste, improve the processes and aggregate value to the product for client satisfaction.

The LEAN philosophy becomes a strategic ally for construction businesses that wish to reduce waste rates and optimize the delivery times of engineering projects, this is why recently, lean construction has been successfully implemented in the construction industry [3]. The application of Lean tools in construction works has been identified as a strategy to reduce the total cost of the project and the finishing time by minimizing activities that do not add value and obstacles to achieve a reliable workflow during the production process [4].
The construction businesses that have implemented the Lean tools in their processes or activities developed on different projects, have evidenced the importance of these tools through successful results that improve these practices, demonstrating that the Lean principles allow the improvement of construction efficiency by synchronizing the construction process and the elimination of waste, which can also have a positive impact on the environment [5].

Line balancing is a Lean tool based on the location and activity transfers avoiding uncoordinated activities with the purpose of improving and maintaining a continuous flow of activities and planned processes for the development of the project, exploring work areas and securing that activities are not performed on different locations and at the same time, all this with a planned schedule in only one worksheet of paper as well as in Japanese construction practices [6].
The elimination of waste, the monitoring of processes, flexibility, optimization, the willingness of the personnel, the continuous and efficient improvement and value for the client have been presented as some of the key drivers of the Lean philosophy [7].

This research shows the productivity of workforce in activities of plastering and internal detailing of two-story masonry houses, taking as sample the housing project Callejas del Este, located in Cucuta, implementing the Lean tool denominated Line Balancing. It has been demonstrated that Lean construction has a significative potential for its implementation in construction projects and its constantly receiving attention around the world [8].

2 Methodology

In the work schedule used for the monitoring and control of activities, the Lean tool denominated balanced scorecard was used as a graphic representation to visually facilitate the conflict between activities. With the collaboration of groups of interest and the continuous improvement, the team members can identify opportunities to eliminate activities that do not add value [9]. The activities of plastering and detailing of houses were defined within the activities program. With the help of the Lean tool "balanced scorecard" the overlaps of the remaining activities were identified.

2.1. Scheduling analysis

The critical path of the project defined that the priority is to assign specific activities for the accomplishment of the construction program, a set of activities were considered for the critical path network and also delays in the defined activities were identified. Within the analysis of the critical path for the housing project Callejas, previous activities were found to the ones analyzed in the project, these indeed influenced in the advance and the development of the assigned tasks. Each planner prepares work plans weekly to control the workflow, if tasks are not completed in time, they must determine the cause and develop an action plan to prevent future failures [10].

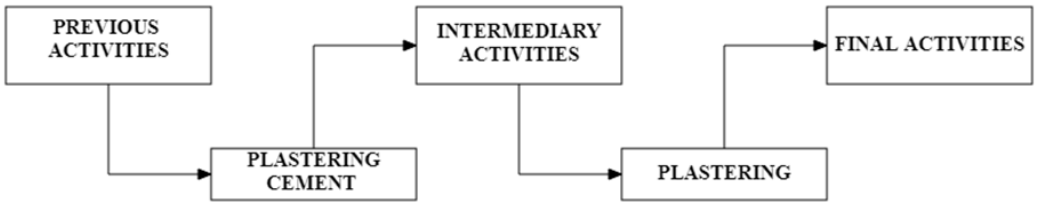

Figure 1. Analysis of construction program

2.1.1. Previous activities

Were composed by all the necessary activities in the beginning of the first plastering stage. According to the program, some activities had to be finished before wall plastering, one of these was the electric and hydro-sanitary installations.

2.1.2 Intermediary activities

These were composed by activities performed between plastering and the beginning stage of detailing. According to the program, some activities that needed to be finished before starting the detailing of walls were, the refining of floors and stairs and tiling bathroom and kitchen walls both in the first and second floor of the house.

2.1.3 Final activities

These were composed by the activities necessary for the satisfactory delivery of the project, which according to the program corresponded to the installation of aluminum carpentry, electric wiring, installation of wood carpentry, installation of hydro-sanitary equipment and painting.

2.2 Workforce

Table 1. Activities previous to workforce data recollection

Identified activity	Developed activity
Type of contract	During this activity, the employees were hired by agreeing a value with the contractors. This generates an incentive for the employee to finish activities as soon as possible with the purpose of charging more checks.
Work crew	The number of employees hired by the contractor to meet with the programmed activities were identified.
Time of material application	Though the application of balanced scorecards and verbal surveys in this activity, the estimated time each worker used for applying the material was identified. The verbal surveys were performed on key hours for the employee (work breaks and at the end of their shifts).
Daily advance records	Knowing the described variables of workforce and material, control and monitoring formats were generated.
Daily advance monitoring	This activity consisted on determining the duration elaborated by the crew on a workday.

2.3 Identification of activities

Sub-activities that made part of the activity described in the main program were identified and were classified considering the definition of productive activities (P), contributive activities (C), and non-contributive activities (NC).

Table 2. Classification of work in walls and tiles

Sub-Activity	Classification
Dilations	P
Application of paste and plaster	P
Sanding walls	P
Cutting edges	P
Cleaning	C
Scaffold transportation	C
Material transportation	C

Table 2. (Continued): Classification of work in walls and tiles

Tool transportation	C
Material preparation	C
Conversation between workers	NC
Moving around at work	NC
Sporadic breaks	NC
Hydration of employees	NC
Reunion with the immediate superior	NC
Wait for the material	NC
Reprocessing	NC

2.4 Classification criteria

The results of each balanced scorecard is a percentage of productive, contributive and non-contributive activities, with the objective of correlating the productive level of the activity with the accomplishment of the compromises defined in the activities schedule. Finally, knowing the level of productivity obtained through scorecards, this is compared to the analysis generated by Fernando Botero in 2002 to know the state of the analyzed activity.

Table 3. Classification criteria for the results obtained in the productivity analysis

Productivity level	Minimum	Satisfactory	Outstanding
Productive	50%	55%	60%
Contributive	35%	30%	25%
Non-Contributive	20%	15%	10%

Source: Botero Botero, Análisis de Rendimientos y consumos de mano de obra en actividades de construcción, 2002.

3 Results

For the interpretation of the data obtained, using as reference the research work of Fernando Botero that shows the results of productive, contributive and non-contributive measuring times in Colombia from 2003-2005, were the general average of time study obtained on a national level for a sample of 24.425 observations in a workday of 8 hours, gave as result that 48.20% of the time is productive, non-contributive time corresponds to 17.7% and contributive time corresponds to 34.1%.

The results were detailed according to the work crews 1 x 0 where 1 corresponds to an official worker and 0 to work assistants.

Table 4. Performance of plastering workers

Work crew				
Official	Assistant	m^2/hour Crew	m^2/Day	m^2/hour-man
1	0	6.4	51.2	6.4
2	0	12.6	100.8	6.3
3	0	14.4	115.2	4.8
4	0	21.8	174.4	5.45

Table 5. Performance of detail of finish workers

Work crew				
Official	Assistant	m^2/hour Crew	m^2/Day	m^2/hour-man
1	0	4.5	36.2	4.5
2	0	8.6	69	4.3
3	0	15.6	125	5.2
4	0	18.6	149	4.6

3.1 Analysis of results

The interpretation of the data obtained with the elaboration of lines of balancing and field observations along with its synthesis in tables 4 and 5 correspond to the analysis and interpretation of the same, whose results we can describe as the following:

The application of plastering compared to the finishing or detailing, is more productive due to its advance in m^2 presented in its application per work hour, this advance is due to the quantity of mix applied to the wall and its filling process. The performance in the application of finishing or detailing is less productive compared to plastering, due to the carefulness workers must have when applying it, each application of steel wool leaves a vein that must be eliminated with a new one, also an identified factor is the drying wait of all the layers for posterior sanding. The implementation of Lean construction is mostly based on organizational learning and knowledge building, which at the same time is promoted by Lean techniques [11].

Important factors that do not contribute to the development of the project were also identified, among them are the conversations workers maintain in numerous crews, where the % of non-contributive time is considerable; out of every 10 minutes analyzed in the activities of numerous work crews, 2 minutes are lost due to conversations between workers. Hydration of employees adds to non-contributive times, where the movement of the personnel is inherent in the search of water or other liquids. The lack of planning of activities along with the material needed for their execution play an important role at the time of contributing to the project. Stopping an activity to prepare mixes does not contribute to the advance of the project.

The previous skills and experience of the worker become an important factor for the development of the activity when performing tasks in the stipulated time established in the program, an expert improves the performance of the project considerably, a beneficial situation for the production time by improving the economy of the project. The absence of a good management system in the construction project can generate various problems that could increase the costs, a late delivery of the project and low quality could reduce the benefits of the contractor [12].

4 Conclusions

The use of tools and equipment for mixing can considerably improve the execution time of activities by significantly reducing the non-contributing times destined to the manual mixing of the different materials used for construction. The elaboration of an interview that contains questions about previous experience in past jobs, becomes a key point when selecting employees for the development of the necessary activities in the project, the experience and skills of the employee for the performance of tasks implies important contributive times for the accomplishment of the stipulated time of the program. Non-contributive times of numerous crews are considerable due to the cease of activities caused for sporadic talks between workers, situation that can be fixed with the reduction of crew personnel or individual tasks.
The implementation of hydration spots close to the working site can considerably reduce moving times of personnel looking for hydration, this way reducing non-contributive time destined for this type of breaks. The use of supports, scaffolds or portable work tables can improve the times of application of the plastering and finishing activities, commodities that generate productive time to the execution of the activity and favorably contributes to the economy of the project.

The implementation of the Lean tools in civil engineering projects, is an innovative help for the accomplishment of the programmed activities, not only for meeting the times but also for the improvement of the economy of the project through the reduction of waste both in time and materials. Being able to identify contributive, productive and non-contributive activities in the different processes of the project, notoriously improves its rentability, situation that is reflected on the value given to the client. Eliminating non-contributive times and activities that do not generate value in an engineering project is the main focus of the lean methodology, the implementation of its tools implies an improvement of the processes.

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Received: October 22, 2018; Published: November 26, 2018