

# The Planning in Lean Construction Methodology At Colombian Civil Sector

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**ABSTRACT:** *Civil construction sector in Colombia's economy is one of the axes of national development as it presents itself as job creation for different workers from different operational activities. In order to plan the construction activities and give a logical sequence to the construction processes, the administrative work area elaborates a strategic operational planning for the activities execution. However, the magnitude of the construction projects and their correct synchronization in the operational execution put a limit in the normal flow of the planned activities. One of the frequently used quality strategies to manage planning in construction projects is the Lean Construction philosophy through the implementation of the last planner. It is an organizational management tool for addressing and managing internal planning activities. In this article, short-term planning (weekly planning) is highlighted based on a case study that focuses on the implementation of a project in a civil sector in Colombia. The results show that the organizational management is closely related to the control, execution, and evaluation and monitoring of the constructive activities.*

**KEYWORDS:** *Lean Construction, Last planner system, weekly planner, civil engineering.*

## 1. INTRODUCTION

Activities such as techniques, processes, procedures and execution methods in the civil construction sector in Colombia represent one of the principal economical activities of the country.

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According to [1] and [2], the statistics of workforce in the third quarter of 2016 in the civil construction sector at Colombia comprises 30,929,685 m<sup>2</sup> in civil work, 6,160,152 m<sup>2</sup> in inactive work and 4,286,318 m<sup>2</sup> in completed works. However, in [3], they argue that one of the causes of the loss of focus in planning construction is associated with the loss of knowledge about short-term and weekly planning for construction projects, causing a decrease in project's productivity and profitability.

The Lean Construction methodology is one of the strategic industrial engineering to resolve problems about planning organizations. This approach was initially introduced in the automotive sector of Toyota in Japan, which focuses on "increasing the value of the product by eliminating any type of activity that does not generate value for the customer, known as a loss" [4] [5]. One of the fundamental aspects to be studied in this methodology is the management of the short-term planning of the activities executed in the civil sector, which is known in the methodology as a last planner in the Lean construction. According to [6], it is essential to adopt a methodology for planning the operative construction activities, responsible for their process and their association to time frame in which they will be executed (short term). In [7] and [8], they emphasize the importance of on-site planning management associated with some of the main existing quality methodologies, such as the just-in-time practice, reduction of variance in labor productivity indicators, elimination of waste and simplification of the operation as added value in the last planner. [9] and [10] asserted that the short-term (weekly) planning methodology concentrates its efforts on the quality management of work and executes a proactive management of the weekly assignments in construction as solution to evaluate current production planning practices and improve them, if necessary [15] [16].

The current planning methods used in the industry tend to focus on the project planning levels rather than the production levels [11] [12]. In the search for the development of the last planner

and its management as methodology of compilation, documentation, implementation and quantitative control of the construction processes, a contextualization of short-term planning is presented in Section 2. In Section 3, a specific case study is conducted in the construction sector, focusing on its development through weekly planning (chronological term) [13] [14]. Further, the results and analysis of the case study are presented as well. Finally, Section 4 presents the conclusions related to the development of this research.

## 2. LEAN CONSTRUCTION PHILOSOPHY: THE DEVELOPMENT OF THE LAST PLANNER

One of the quality management stages based on the philosophy of Lean Construction is known as "the last planner" [17] [18]. The main objective of this strategy is to determine a planning of the constructive activities and to carry out an inspection, monitoring and control according to its scope in the time horizon. Works in [19] and [20] establish one of the fundamental phases in the control of construction processes, namely the short-term planning.

### 2.1 Short-term Planning (Weekly Planning)

Short-term planning or weekly planning describes in the greatest possible detail relevant to the Lean Construction philosophy. For example, Figure 1 illustrates the execution of the construction activities in a period of time not exceeding one week. According to [21] and [22], this type of planning involves those responsible for the operational work of the organization (corps of engineers, work crews, contractors, and support teams, among others). Taking into consideration the medium and long term planning, this type of planning aims to determine time horizon (periodic capacity) and activity horizon (production capacity) and a specific schedule for the execution of the construction activities. In [23] and [20], they state that through this planning, it is possible to determine exactly where the constructive activities is taking place.

The short-term planning system evaluates six criteria in the execution of the construction activities, namely the:

i) Percentage of Completed Activities (PAC): [24] and [25] proposed one of the important factors in this type of weekly programming, namely the percentage of completed activities (PAC). This indicator is the result of the number of activities performed in relation to the total activities assigned for the week (Figure 1). In order to

calculate the PAC, a review of these activities is carried out on site, which occurs between 5 and 6 business day after its planning. During this process, a review in the development of this project is performed and the percentage of activities [26,27] completed in relation to total of activities scheduled is established. The compliance factor follows the following evaluation criteria: Good performance is above 80%; Regular performance [28] is between 80% and 60%; Poor performance is below 60%.

LD CONSTRUCTION		Goal	Weekly Gantt Chart							Causes of non-compliance							
Activity	Responsible	committed	Achieved	21	22	23	24	25	26	27	Prerequisite	Lack of materials	Lack of labor	Changes in project	Lack of tools	Lack of supplier	others
				F	S	M	T	W	T								
Office electrical installation	JT Construction	100%															
Bathroom stucco	ABACAF	75%															
Security installations	ESLIN	30%															

Figure 1: Example of Short-term Planning [9]

ii) Order and Cleanliness:

This item evaluates the order and cleanliness of the work site [27], order of workers' materials and compliance of the cleaning days at the workplace.

iii) Quality

This item evaluates the quality of each of the activities of the product and the process. With the support of the civil engineer, the quality of the work and compliance with the technical specifications demanded by the product is analyzed.

iv) Personnel Administration

This criterion is evaluated according to the payment made on time and the delivery of invoice in the administrative department of social security. It also assesses the use of personal protection elements within the work, constant communication between worker and contractor and timely payment of salary to workers by contractors.

v) Industrial Safety

The industrial safety is qualified according to the report of accidents that are handled monthly in the work and according to the Severity Index and Last Planner criteria, the severity of the accident and the impact on the productivity of the work are determined also.

vi) Resource Management

This item qualifies the good use of the resources granted by the company and the disposal of the same within the work. It also analyzes the sense of belonging of the workers and care for the raw material and tools needed in construction. In the weekly planning, there are four

meetings (one per week) in which the different points to be discussed about the construction project and the fulfillment of the tasks are mentioned; Further, in meetings, pending issues of the week are discussed, respective doubts are clarified and problems of the previous week are solved immediately. The rating system follows the following order according to the criteria that are evaluated.

Table1:Qualifying criteria in weekly planning

Criteria	10 Points	5 Points	0 Points
PAC	>80%	80%-60%	<60%
Cleanliness and order	No remarks	Less than two remarks	Two remarks or more
Quality	No remarks	Less than two remarks	Two remarks or more
Personnel management	No remarks	Less than five remarks	Five remarks or more
Industrial safety	No remarks	Less than two remarks	Two remarks or more
Resource management	No remarks	Less than five remarks	Five remarks or more

The additional criteria for compliance with the weekly work activities-PAC (order and cleanliness, quality, personnel management, industrial safety and resource management) are evaluated according to the weekly planning qualification values defined in the Lean Construction methodology, as shown in Table 1. From these, a total score per week is established and published for the knowledge of the staff in the organization, as shown in Figure 2. Finally, the ratings established for each of the weeks are consolidated in the Monthly Qualification System, as presented in Figure 3. This monthly qualification system is consolidated quarterly, semiannually and annually, for purposes of control and continuous improvement of the Lean Construction methodology.

QUALIFICATION OF CONTRACTORS AND ADMINISTRATION						
PERIOD TO EVALUATE (WEEK):						
CONTRACTORS	PAC (80%)	ORDER AND CLEANLINESS (10%)	QUALITY (10%)	PERSONNEL MANAGEMENT (10%)	INDUSTRIAL SAFETY (10%)	RESOURCE MANAGEMENT (10%)
Pablo Acuña	10	10	10	10	10	10
Ernesto Murillo	10	5	10	5	10	10
Administración	10	10	10	10	10	10
Juan Guillermo	10	10	5	10	10	10

Figure2:Example of weekly qualification Lean Construction

QUALIFICATION OF CONTRACTORS AND ADMINISTRATION		PERIOD TO EVALUATE (MONTH):	
		NOVEMBER	
ASPECTS TO BE QUALIFIED	PAC (80%)	ORDER AND CLEANLINESS (10%)	QUALITY (10%)
WEEK CONTRACTOR	1 2 3 4	1 2 3 4	1 2 3 4
Pablo Acuña	10 10 10 10	10 10 10 10	10 10 10 10
Ernesto Murillo	10 10 10 0	5 10 10 10	10 10 10 10
Administración	10 10 10 10	10 10 10 10	10 10 10 10
Juan Guillermo	10 10 10 10	10 10 10 10	10 10 10 10

Figure3: Example of Monthly Qualification Lean Construction

### 3.0 3. RESULTS AND DISCUSSION

A case study in the implementation of Lean Construction philosophy was carried out in a construction project of Bucaramanga city, Colombia. The construction project was studied in depth focusing on its the short-term planning, which relate to the level of relevance of the operational work activities, considering the contractors in the process (being the main responsible for the operational activity), its interrelation and participation with the other components of the company (Department of Equipment, Purchasing, Suppliers and Administration).

WEEKLY PLANNING - LAST PLANNER																
Start date	02 December		Week	1												
Review date	05 December		Elaborated	Eng. Gustavo Hoque												
Date Culmination	08 December		Revised	Eng. Luciano Ariza												
LOCATION	ACTIVITY	RESPONSIBLE	COMMITTED	REALIZED	PAC	COMPLIANCE CONTRACTOR	Weekly Gantt Chart					Causes of non-compliance				
							Dec 02	Dec 03	Dec 04	Dec 05	Dec 06	Of the Contractor	Not attributable to the Contractor			
Torne 5	Fused walls floor 1-2	Pablo Acuña	100%	100%	1	1										
Torne 5	Fused Planes Floor 1-2	Pablo Acuña	100%	100%	1	1										
Torne 5	Fused from Walls floor 3-4	Pablo Acuña	75%	75%	1	1										
QUALIFICATION CONTRACTOR 1		Pablo Acuña	100%	100%												
Torne 5	Installation hydraulics floor 1-2	Ernesto Murillo	100%	100%	1	1										
Torne 5	Reverage installation in tower planning	Ernesto Murillo	100%	100%	1	1										
Torne 5	Installation sanitary network floor 3-4	Ernesto Murillo	100%	80%	1	1										
QUALIFICATION CONTRACTOR 2		Ernesto Murillo	67%	67%												
Torne 6	Delivery of structural plans Torne 6	Administración	100%	100%	1	1										
Torne 6	Delivery of architectural plans Torne 6	Administración	100%	100%	1	1										
QUALIFICATION CONTRACTOR 3		Administración	100%	100%												
Torne 5	Delivery of electrical network of urbanism	Juan Guillermo	100%	100%	1	1										
Torne 5	Electrical installation 1-2-3 floor and 4	Juan Guillermo	100%	100%	1	1										
QUALIFICATION CONTRACTOR 4		Juan Guillermo	100%	100%												

QUALIFICATION OF CONTRACTORS AND ADMINISTRATION						
PERIOD TO EVALUATE (WEEK):						
CONTRACTORS	PAC (80%)	ORDER AND CLEANLINESS (10%)	QUALITY (10%)	PERSONNEL MANAGEMENT (10%)	INDUSTRIAL SAFETY (10%)	RESOURCE MANAGEMENT (10%)
Pablo Acuña	10	10	10	10	10	10
Ernesto Murillo	5	10	10	10	10	10
Administración	10	10	10	10	10	10
Juan Guillermo	10	5	10	10	10	10

Figure4:Example of weekly qualification System Lean Construction, first week of December

Initially, a total of 20 contractors participated in the Lean Construction methodology, and the different criteria defined in the weekly planning were evaluated. The weekly qualification record was controlled through the quality format called R-ING 129, a document belonging to the study organization, which is presented in Figure 4. This



document recorded the PAC activities for each contractor and evaluated in the four weeks of each month, for a total evaluation of 22 weeks of total study. With respect to the results of the additional criteria for PAC (order and cleanliness, quality management, industrial safety and resource management), these were carried out according to the observations made by the researcher and the civil engineer on site considering the qualification criteria And evaluation are presented in Table 1. From each weekly rating, a consolidated monitoring of the information was carried out during the investigation period, in order to feedback and improve the Lean Construction methodology developed in this case study.

The first result generated from the consolidated analysis of the weekly rating Lean Construction is known as the percentage of total accumulated activities, corresponding to the PAC rating corresponding to the 22 weeks analyzed. The results are presented in Figure 5:

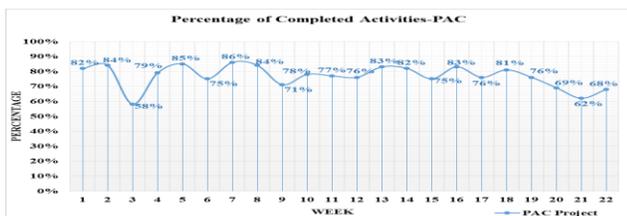


Figure5:Percentage of completed activities –PAC

The percentage of completed assignments (PAC), as can be seen in Figure 5 shows a variable performance of weekly assignments as a result of changes in the working conditions of each of the qualifying activities (lack of Personnel, environmental issues, suppliers, and others). It can be observed that there is a decreasing behavior during the last four weeks of study. This trend is justified by the increase of constructive work in the delivery of the properties to the owners due to the addition of the activities of work rated weekly. The next criterion is Order and Cleanliness. Figure 6 (a) shows the respective indicators for the months of December, January, February and March, namely 9.14; 9.89, 9.83 and 9.89 respectively, as a result of the implementation of toilet schedules. For the month of April and May, there is a decrease in average compliance with 9.61 and 9.60, respectively, due to the lack of lean methodology resulting from the entry of new contractors to the work. The quality criterion and its respective qualification can be observed in Figure 6 (b). As can be observed, the performance of the quality criterion shows

compliance scores favorable to the work, thanks to its average score value that is above the 8.5 point scale. The next criterion to qualify for weekly planning is staffing, as can be seen in Figure 6 (c). For the present analysis, there is a high variability behavior during the months investigated in the project (9.62, 8.56, 7.94, 8.92, 8.62, 8.60 in the months of December until May respectively). The reasons for the variability phenomenon are presented below: Payment of social security of workers, use of personal protection elements, among others. Industrial safety is presented as the fourth criterion within the weekly qualification in short-term planning, as can be observed in Figure 6 (d). A score of 10 points was obtained for the months of December, January, March and May 2010, as a result of good safety practices in the work area due to the use of personal protection elements, assistance to safety training, etc. In the months of February and April, there is a decrease, with values of 9.88 and 9.89 respectively. This is the result of two accidents with disabilities that occurred during this period of analysis, affecting the integrity of the workers involved and their absence at work. Finally, the classification of the resource management criterion is presented, as shown in Figure 6 (e). In this criterion, an optimum rating behavior can be analyzed, obtaining scores above 9 points, due to the good management and care of the work items (tools, raw material, equipment, etc.) granted by the administrative team of the Construction project.

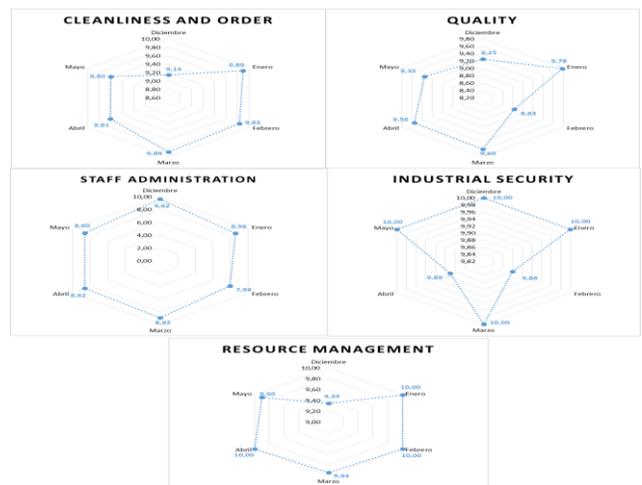


Figure6:Qualifying criteria graphics for Lean Construction

#### 4.0 CONCLUSION

The Lean Construction methodology is a strategic tool for achieving continuously of the weekly activities construction. The correct use of the Last planner technique within the philosophy allows the integral management of the planning, analysis, monitoring,

control and improvement of the constructive activities and their interrelation and synchronization with the medium and long term planning.

The activity planning system, known as the last planner, allows controlling the activities carried out by those responsible for the civil project and managing the progress of the different construction processes based on the weekly qualification by means of the percentage of completed assignments (PAC). The results shows that the implementation of Last planner methodology increases the PAC levels inside the construction activities at the Colombian civil sector and reduced and considerable delays in the project's long-term planning can be avoided.

The results obtained from the different evaluation criteria (Cleanliness and order, quality, staff administration, industrial security and resource management) show an integral development of the Last Planner System as a total quality element of the Lean Construction philosophy. The Qualifying criteria in weekly planning allowed to generate a management environment of the Lean Construction methodology within the organization and the birth of a commitment of continuous improvement by the workers of the company evidenced in the qualifications superior to 80 percentage points in each of the criteria evaluated.

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