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Original Article

Lean Operations Management Model to Increase On-Time Project Delivery in a Construction Company

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Abstract *- The construction industry is exposed to more significant risks and unforeseen events than other industries, as projects are often developed under unpredictable circumstances due to different factors that must be taken into account during their execution. In addition, delays in the construction industry are considered one of the biggest problems faced by projects, as they can lead to cost overruns, disputes between parties, project abandonment and even lawsuits. The objective of the present study aims to increase the on-time delivery of construction projects by addressing the reasons and root causes identified in the study. The innovative proposal to avoid project delivery delays is introducing a Lean system based on the Last Planner System (LPS) methodology, designed to support production planning and control in construction projects. The proposed model was validated using a pilot plan in a project of tracks and greenways carried out in Lima, obtaining; as a result, a decrease of 8% in the time of project delays with respect to the initial deadline, an increase of 22% in the percentage of the completed plan and a decrease of 5% of the stoppages due to rework. The research confirms the success of the lean construction philosophy and its powerful tools, such as the LPS, which will serve as a reference for its application in other companies with similar characteristics.*

Keywords *- LPS, Construction projects, Lean construction, Planning, Lean management.*

1. Introduction

The construction industry is one of the main drivers of the global economy, and Latin America is no exception to this trend. However, the coronavirus pandemic has disrupted the execution of projects in the construction industry, triggering one of the most significant economic recessions in recent history. Nevertheless, the construction industry in Latin America is benefiting from a faster-than-expected recovery, as a side effect of the latest US stimulus package, despite the continued increase in Covid-19 cases. According to Global Data, project execution in Latin America will increase by 5% in 2022, reaching $545.6 billion, compared to $519.4 billion in 2021 [1]. In Peru, the construction sector was one of the most affected by the pandemic, according to the National Institute of Statistics and Informatics [2], in the first quarter of 2020, there was a 13.3 % decline in GDP compared to the previous year, due to the suspension of works due to the national health emergency. However, it has had faster growth than expected; during the third quarter of 2021, the gross value added grew by 23.2% concerning last year's period. Because private and public works are being carried out more in line with the plan to reactivate economic activity under the current conditions [3].

That said, the construction sector has been facing challenges such as the need for adequate operational management for the procurement and purchase of materials which leads to errors that significantly impact the execution of completion plans in construction projects. In addition, delays in the delivery of materials lead to the violation of the pace of work of organizations; downtime requires additional labour costs, affects the quality of products, and degrades the technical-economic indicators of construction [4].

Given the difficulties that can generate problems in the construction sector, several authors have proposed several solution tools to deal with this phenomenon. First, a case that was carried out in a construction site of an industrial building in Suzhou, China, evidenced that to maximize the value of the project and reduce waste and the cost is beneficial to apply Lean Construction (LC) and Lean Construction Management (LCM) techniques was performed which were divided into five categories: LPS, Kanban, Just In Time (JIT) and prefabrication, digital technologies, and IoT, quality, and safety and continuous improvement and Scrum; managing to resolve more than 90 % of defects effectively [5].

Secondly, there was a case study of a construction site in Russia where to address delays in the delivery of materials that lead to downtime. A system of inventory control of industrial materials based on one of the JIT tools was used, for which daily production delivery schedules were developed, thus allowing to order products precisely at the time required by the customer. As a result, the production cycle time was reduced by 10% [6].

In the literature reviewed, it is observed that lean thinking and LC tools are considered the basis for improving efficiency and sustainability in the industry [7-9]. The study evaluates how to have a knowledgeable and skilled LPS facilitator to improve construction productivity. The structure of this project follows the following sequence: in section 2, the literature review and analysis are located; in section 3, the validation of the proposal is developed; in section 4, details the discussion; in section 5, the conclusions are made.

2. Literature Review

2.1. Adequate Planning in the Construction Sector

According to previous research, proper planning allows setting objectives through strategic means to achieve them so that each process is mapped. That said, one of the investigations details the development of a mathematical formulation that allows solving the problem of the number of materials required at the project site, in which an auxiliary warehouse is considered. On the other hand, the linear programming model considers the uncertainty of parameters such as the cost and quantity of materials used in the projects [10]. However, other authors detail that the lack of planning of material orders affects the cost of maintenance and the cost of shortages, which is why a computational framework using RSM is proposed, which includes a Central Composite Design (CCD) and a Variance Dispersion Graph (VDG), which aims to provide the maximum savings of time and resources needed in terms of crucial performance [11].

2.2. JIT, VSM, 5S Applied to the Construction Sector

According to previous research, implementing lean practices during the project, the JIT system, 5S', contributes to improving the performance of a construction project. For this reason, research details that the LPS tool allows planning and scheduling defined construction schedules that help in the detailed planning of each process. Likewise, the JIT methodology in the construction industry is responsible for ensuring that resources are available at the right time and in optimal quantities [12, 13].

In addition to several studies, the Value Stream Mapping (VSM) tool allows the mapping of internal processes to identify problem areas and waste in projects. Once the problems have been identified, ideal and future state maps of the activities are prepared, eliminating unnecessary activities that do not add value to the projects [14]. Some case studies show that the value stream mapping substantially increased productivity and thus reduced project duration by 13 days, saving about 30% of the expected completion time after implementing the Lean philosophy [15].

2.3. The Planning System in the Construction Sector

In one study, the authors proposed an LPS-based model in which monitoring was focused on planning reliability, not financial metrics, and management decisions were based on planning reliability, a prerequisite for cost and progress measures [16]. Also, in another similar study, all functions of the LPS tool were implemented on-site, supported by seven hours of weekly assistance from the LPS facilitator [17].

On the other hand, in another study, a new work rhythm was implemented using BIM-RFID-LAP technology, which allowed them to observe contractors the situation of the job site to differentiate the requirements of the necessary resources for proper planning and thus accelerate the process of material flow in construction projects [18]. In addition, it has been proposed that 'real-time tracking of materials' allows the evaluation of the accuracy of systems in which the actual movements on the job site are compared. Similarly, his model proposed that by grouping materials from several suppliers into packaged kits and consolidated deliveries, reliable deliveries for requests of less than 48 h were achieved [19, 20].

2.4. Lean-BIM Models-Planning Systems in the Construction Industry

According to previous research, effective project management is critical in increasing the company's competitive advantage and organizational performance [21, 22]. Consistent with those mentioned above, implementing the BIM tool guarantees construction processes more efficiently since it is outlined to problem-solving through design stages, aiming to increase stakeholders' predictability and interaction [23]. On the other hand, the LPS methodology reflects management thinking based on the assumption of scheduled tasks that include uncertainty and interdependent constraints to follow with monitoring that focuses on planning reliability. However, financial metrics are not considered. Likewise, the authors state that evaluating efficiency through the defined process allows for better performance that focuses on value creation and eliminates activities that do not add value to the project. With the implementation of the LPS, it can face various challenges and causes of variation, which is why it increases the chances of a successful implementation of the LPS [24, 25].

2.5. Construction Project Management

The authors addressed the construction industry's schedule delays and cost overruns using the Important Index (IMPI), which assimilates both frequency and effectiveness indices [26]. Also, it ensures that the organizational characteristics of the construction companies and the project environment greatly influence the planning and scheduling efforts. A fast project management system that allows the project planning stage to be carried out in the best way. It could also be ensured that cost overruns, rework and demolition, and disputes are the main consequences of such variations [27-29]. Therefore, strategies should be focused on minimizing these variations.

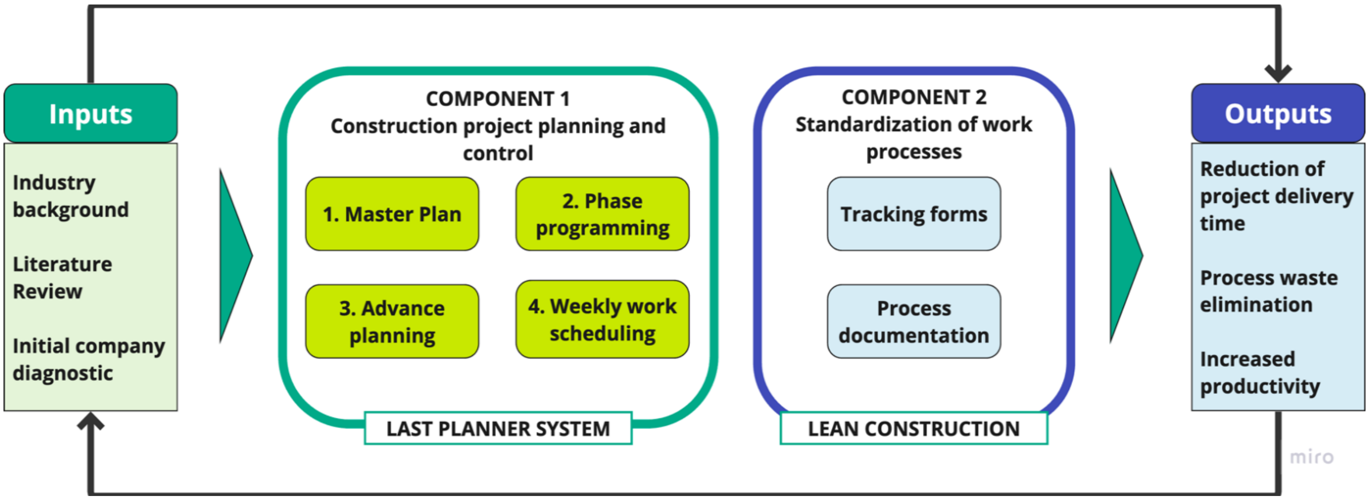

Fig. 1 Proposed Last Planner System model, Adapted from [5],[27],[28]

3. Proposed Model

For the present case study, the Last Planner System model has been developed, as shown in detail in Figure 1. This study aims to reveal and confirm the use of the Last Planner System model in a scenario little investigated by the literature in order to establish a precedent of scientific evidence that contributes to the effectiveness of this study in companies of the construction sector and, in this way, contribute to the reduction in delivery delays, improve customer satisfaction and increase revenues. In this sense, it is essential to highlight the novel model of this research, where the Last Planner System and work standardization tools are implemented and integrated innovatively, in an uncommon sector, with the same objective: to increase the efficiency of the company.

The VSM tool will capture the percentage of waste generated in each activity by mapping the processes' current state. With the information collected, we will proceed with the model, which is comprised of 4 phases: (1) Master Planning, (2) Phase Programming, (3) Advance Planning, and (4) Weekly Planning.

3.1. Model Components

This section presents the components proposed in this academic paper to increase on-time project delivery, as seen in Figure 1.

3.1.1. Production Planning and Control for Projects

Phase 1. Master Planning

For an ideal definition of strategic planning, the following procedures were proposed:

- Define the project's scope: Develop a detailed description of the project, describing the limits by specifying the requirements collected, which should be done every time the profitability of a project is analyzed. Then proceed to hierarchically decompose the total scope to be performed by the project team to meet the project objectives and create the required deliverables.
- Elaborate preliminary budget: Elaborate on the economic valuation of new or remodeling work in order to determine the estimated value of the same for the allocation of the required budget; this will be done at the beginning of the definition of the scope until the delivery of the detailed budget to carry out the purchases of the project.

Phase 2. Phase Scheduling

In this phase, all those responsible for the project activities will be invited to participate so that the entire team has visual access to the objectives and strategies defined during the elaboration of the phase programming. Discussions on the activities to be carried out and the commitments involved will be held in a space defined as the "Big Room".

Phase 3. Advance Planning

The aim is to increase the detail of the activities defined in the previous step. During the lead-up time, specific tasks are identified within the broader activities. Each task is examined to ensure that the requirements are identified and that the work assigned to the ultimate planner is appropriate.

Table 1. Indicator table

Indicator	Formula
Percentage of Plan Completed (PPC)	$\frac{\#\ committed\ tasks\ completed}{total\ committed\ tasks} \times 100\%$
Percentage of time delays concerning the initial deadline	$\frac{\#actual\ days\ to\ closing - Initial\ deadline\ days}{initial\ term\ in\ days} \times 100\%$
Percentage of stoppages due to rework	$\frac{hours\ of\ browning\ due\ to\ rework}{final\ deadline\ in\ hours} \times 100\%$

- Constraints analysis: Analyze that the necessary conditions are met to execute an activity. The analysis must be accompanied by strategies to solve the problems detected in time to execute the activities as planned in the look-head meeting.
- Executable Work Inventory (EWI): When activities do not have any restriction that prevents their ability to be executed, they must be stored in a list of ready-to-execute activities, called executable work inventory.

Phase 4. Weekly Work Planning

The weekly plan intends to plan the following week's schedule on assignments that can be completed and to save resources by avoiding launching production orders on tasks that cannot be completed. The objective is to create a work plan committed to the ultimate planners with clear quantitative goals. Therefore, the tasks completed during the week should be available in the executable work inventory (EWI). Furthermore, if there is a low probability of meeting the planning look ahead, the resource planning and assignments to be accomplished should be disclosed in the weekly plan, and resources should be adjusted to develop another substitute activity.

- Causes of Non-Compliance (CNC): The CNC analysis will determine the cause of the discrepancy, which will help to know which causes are recurrent and can be solved in the coming weeks.

3.1.2. Standardization of Work Processes

The causes of failures will be categorized under the work standardization methodology, proposing preventive and corrective strategies for the most critical causes. In addition, it is proposed to establish a follow-up document for the most demanding procedures.

3.2. Indicators Model

For the evaluation of the proposal during its implementation, monitoring and control indicators will be proposed. The indicators are aligned with the problem and will be compared from the beginning to the end of the project to check if the proposal has impacted the organization as expected. Table 1 lists the indicators aligned with the components of the model.

The following is a summary of the company's situation before the pilot test and the expected results based on the literature reviewed:

Table 2. Indicator situation pre-pilot and expected result

Indicator	Situation pre-pilot	Expected result
% Plan Completed (PPC)	54.44%	43.26%
% Time delays concerning the initial deadline	64.75%	90%
% Stoppages due to rework	8%	1%

3.3. Validation

3.3.1. Initial Diagnostic

In order to carry out a case study, a follow-up of historical data of the company under study was conducted. To this end, the sales data for the last five years was consolidated to categorize the projects that most affect the organization's performance, obtaining that the projects that contribute the most to the company's turnover are the projects of roads and sidewalks, representing 75% of the annual turnover. In addition, it was identified that the high rate of projects delivered after the deadline generates an economic loss amounting to PEN 1,834,276, equivalent to 37% of the company's annual turnover. This is why we proceeded to analyze the causes of the problem in this type of project. Thanks to this diagnosis, it was possible to identify the three main root causes that most affect the problem: rework on site (with an impact of 47.9% on the problem), calculation of insufficient days (with an impact of 27.1% on the problem) and work stoppages (with an impact of 16.5% on the problem).

3.3.2. Validation Design

In order to validate the expected results, the implementation of the proposed solution will be carried out in a project of tracks and sidewalks of short duration. The model proposed to carry out this pilot comprises 4 phases (Master Planning, Phase Scheduling, Advance Planning, and Weekly Work Planning). When correctly applied, it will allow for fulfilling the main objective, which is to improve the efficiency in the delivery of projects.

First, when starting a project, the master plan must consider the deliverables and milestones. In this case, the LPS was initially implemented in the perimeter fence, and then the entire project was controlled by the LPS (Elaboration of Look Ahead programming). Second, through the Look Ahead programming, we sought to have a clearer vision of the planned work and to anticipate the various variabilities and problems that may arise when trying to carry out the activities on the planned days. All these activities have a beginning and an end, each with its limits. Weekly meetings accompany this four-week LSP implementation. Establish key weekly work points to achieve the highest percentage of these planned activities. Third, the Weekly planning was prepared, considering the activities released or those about to be released, based on the look-ahead schedule, the segmentation of activities, and previous meetings with the contractors. During the weekly planning meetings, the following were discussed: Counting the activities that were achieved, listing, and analyzing the Causes of Non-Compliance (CNC), presenting the tentative schedule for the next week, reviewing and approving the weekly work plan, and reviewing the constraints that may affect the weekly work. Finally, a department was assigned to prepare periodic reports on the work's progress and delay for proper follow-up, budget control, and programming. To this end, it was necessary to specify the policies for compliance with standards, presentation, and dissemination of integrated SPL strategies. In addition, during the weekly planning and coordination meetings with the supervisors, the work progress indicators mentioned in the reports are measured and controlled.

After having applied the methodology in a project with a duration of 13 weeks, it was possible to validate the implementation of the LPS solution model through the 4 phases, achieve a reduction in the rate of projects delivered after the deadline, from 54% to 46% (a reduction of 8%), reaching the main objective set out in this research.

4. Discussion

4.1. New Scenarios

By implementing a last planner system in the workplace, activities are repeated (improvement in the learning curve), thus reducing errors as activities are performed by more professionals, which in turn represents lower costs for reprocessing. On the other hand, with the help of a quality management system, downstream processing can be reduced, which reduces costs. In addition, GIS also seeks to standardize all processes involved in the execution of the work, facilitating the planning and management of these processes. That said, this analysis will consider industries that have significant similarities with LPS in terms of process flow and characteristics:

4.1.1. Scenario 1: Bridge Construction Projects

Within this division, there are 45% delays in the delivery of these types of projects; these delays are mainly due to unpredictable weather conditions, inaccurate prediction of the production rate of the equipment, and equipment shortages. For the above reasons, implementing the LPS model is feasible.

4.1.2. Scenario 2: Building Projects

Due to the large scale of these projects, much labor is often required throughout the construction process. In addition, construction projects generally require more regulations and codes than commercial construction projects. Within this division, delays in delivering these types of projects are also evidenced in 50%. It is also evident that among the leading causes are shortages or delays of materials, rework or work poorly done, and lack of tools and equipment; for these reasons, it is feasible to implement the proposed model in these scenarios.

4.1.3. Results of Potential Scenarios

Based on the analysis of the scenarios presented in the bridge and building construction scenarios, the following is an evaluation of the improvements obtained with the LPS methodology in the two categories presented as scenarios (see Table VI).

Table 3. Indicator results after implementation

Indicator	Previous	Improved	Expected
% Plan Completed (PPC)	54.44%	46%	43.26%
% Time delays concerning the initial deadline	64.75%	87%	90%
% Stoppages due to rework	8%	3%	1%

Table 4. Potential results in other scenarios

Scenarios	Indicators	Current value	Final result
Bridge construction	% Time delays concerning the initial deadline	45%	43%
	% Plan Completed	75%	90%
	% Stoppages due to rework	6%	2%
Buildings	% Delays in time concerning the initial deadline	50%	44%
	% Plan Completed	75%	87%
	% Stoppages due to rework	5%	2%

As seen from the detailed tables above, the improved model proposed in this project will bring beneficial results to other departments of the research company in terms of process and sales optimization. The effectiveness of the proposed solution model can be verified through simulation to achieve the stated objectives regarding project delivery delays and rework stoppages. It is also essential to evaluate and validate the project's impact from an economic and environmental perspective to understand the economic benefits that the project will bring.

4.2. Economic Analysis

For the financial evaluation of the project, the expected financial cash flows for the five years were made, taking into account all the costs of implementing the proposed improved model and the results of the pilot in which there was an 8% reduction in the project delivery delay. Also considered are the operating costs attributed to the training on the improvement tools. From the cash flow, the financial indicators of Present Net Value (NPV), Internal Rate of Return (IRR), and Discounted Payback Period (DRP) were calculated. It was found that the project yields an IRR of 85.42% and a positive NPV of PEN 208,831, considering a discount rate of 10%, making the project attractive. In addition, in the pessimistic scenario, there is a 10% reduction of savings in benefits of the proposal in the present value of investment concerning the conservative scenario, which is why there is evidence of a reduction of benefit-cost in the cash flow. Finally, the DRP is estimated to be 1.03 years, so that the project would generate profits from this period.

5. Conclusion

Lean thinking and LC tools such as the LPS are considered the basis for improving efficiency and sustainability within the construction industry and can reduce late project delivery by 8%. %. In the same way, in the case of the percentage of the completed plan, the number of completed committed tasks was increased by 22%; likewise, regarding causes of non-compliance, a reduction of 36% of causes of rework in the project was reflected. Likewise, during the first four weeks of implementing the LPS methodology, 11% of activities were completed by each project collaborator. However, from week five onwards, there was a significant improvement reaching an average of 84% of activities completed by each person in charge due to the pull and look-at-head sessions that allowed us to be close to our desired percentage of 90%.

After obtaining satisfactory results, it has been possible to demonstrate through this research that the LPS is a methodology that prioritizes the efficiency of the workflow, which makes plans executed more reliably, which can mean a reduction in time and cost, as well as a higher quality and operational reliability.

On the other hand, the present study allows us to expand the literature on reducing the late delivery of projects in a construction company. In addition, based on the research, it is worth exploring the possibility of implementing the proposed model in other types of projects with similar characteristics to the one analyzed.

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