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LAST PLANNER SYSTEM: IMPLEMENTATION, EVALUATION AND COMPARISON OF RESULTS IN THE CONSTRUCTION OF A SOCIAL HOUSING PROJECT IN CHILE

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ABSTRACT

This paper shows a detail implementation and lessons learned from the Last Planner System (LPS) in the context of a social housing program of the government of Chile. Specifically the "Condominio Juanita Aguirre" (CJA) project in the commune of Conchali in Santiago, Chile, which includes the construction of 80 apartments of 56 m², in buildings of 4 stories high on a contractual period of one year. We followed the trajectory from the general contractor perspective, Oval Company, which has extensive experience in the construction of social housing. This company has obtained highly variable projects results in the past, and thus the company decided to implement the Last Planner System (LPS) in the CJA project**.** This research measures the results of the implementation throughout the construction process. Additionally, we make a comparison against previous projects of similar characteristics built by the same company with traditional management systems. Finally, the research shows that CJA project achieved significant improvements compared to previous projects, in the areas of: construction schedule, construction costs, safety, and final quality of housing.

• KEYWORDS

Last Planner System, Planning.

• INTRODUCTION

This paper shows a detail implementation and lessons learned from the Last Planner System (LPS) in the context of a social housing program of the government of Chile. We followed the trajectory from the general contractor perspective, Oval Company, which has

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extensive experience in the construction of social housing. This company has obtained highly variable projects' results in the past in terms of duration and profits, for this reason the company decided to use the CJA project for the implementation the Last Planner System (LPS)**.**

Previous studies have measured the benefits of LPS in many countries and project types (AlSehaimi, Tzortzopoulos, and Koskela 2009, Leal and Alarcón 2010, and Kim and Jang, 2005). This paper differs from other documented applications of LPS in that it has the complete history of the project; the researcher was able to measure the customer satisfaction a month after occupation started, as well as other measurements on cost, and schedule reductions. In addition, this paper shows results on safety measurements. In summary, this paper research focuses in measuring direct and non-direct benefits of implementing LPS. This implementation also explains the role of different last planners including the role of non-traditional planners such as the Safety Specialist.

RESEARCH QUESTIONS AND METHOD

The present study aims to evaluate the results of the implementation of the LPS in the performance of a social housing construction project in Chile. The implementation context is given by a social housing project. Specifically the "Condominio Juanita Aguirre" (CJA) project in the commune of Conchali in Santiago, Chile. It includes the construction of 80 apartments of 56 m², developed in buildings of 4 stories high on a contractual period of one year. However, the company has a 10-moth target for completion, from March to December 2014. This research follows the guidelines of Ballard (2000), Alarcon (2008), and Sabbatino (2011) for the implementation of the LPS.

The research questions in this paper are:

- What are the benefits of applying LPS in this context?
- How do the results of this LPS implementation compares with similar projects?

This research is based on a case study methodology. Following Guidelines from Yin (2013). This research measures the results of the implementation throughout the construction process measuring quantitative and qualitative results (schedule, cost, safety, and customer satisfaction). The second author of this paper, who also is the CEO of the company, facilitated the LPS implementation. Additionally, the authors compare CJA project outcomes to similar projects previously built by the same company using traditional management systems.

APPLAYING THE LPS IN CJA

Next sections describe the implementation of the LPS according to Ballard (2010).

LAST PLANNER MEETINGS

The core of LPS is in the planning meeting (Ballard 1999 and 2010, Ballard and Howell 2003), where the detailed analysis of different activities planned is performed, possible constraints are identified, those responsible for the different tasks are appointed, the Reasons of Non-completion (RoN) are analysed, and the new weekly commitments of all participants in their various specialties are created, all for the purpose of complying with

the proposed goals. The duration of the meetings was around 2 hours and even more at the beginning of the project. However, duration was reduced over time up to 45 minutes due to better preparation of participants.

Participants of the LPS meeting are professionals (e.g., scheduler engineer, safety specialist) and site supervisors, as well as administrative personnel (e.g., logistics chief), who have extensive experience in developing projects with similar characteristics and seniority in the company. In addition, they have been trained in LPS by an organization belonging to a recognized university in Chile. Thus, it can be established that the personnel carrying out the construction and implementation of LPS in the CJA construction work is suitable. This was the first time in the company that all last planners had finished their LPS training before the start of the project.

The meetings were held continuously throughout the construction process, the team measured main LPS indicators, such as the Plan Percent Complete (PPC) results, RoN percentages.

LOOK AHEAD

The analysis and identification of constraints, the commitment to release them, including the responsible and delivery terms are carried out at this stage during the weekly meeting. It is understood that constraints are all those elements or conditions affecting the fluidity of an activity. These constraints are identified according to a 4-week program delivered to each supervisor

The constraints analysis process is performed prior, during and after the coordination meeting (Alarcón 2008). Due to the fact that it is a sequence belonging to a production line, the task to be developed, the person in charge, date or term to run the task and the prerequisites to execute this task must be determined. The state defines whether the task is free from "ok" constraints, or under a release process of "Pending" constraints. This allows assigning defined commitments, responsibilities and impediments that could restrict the job execution.

MEASURING PPC AND RON

The team shows PPC of committed tasks and performance of each site manager graphically, and also reports RoN of tasks not performed. This information is very important in the meeting, as it allows visualizing and analysing indicators of productivity in an extensive and specific way for each supervisor in charge of a job execution.

Due to the characteristics of the project that involve a tight contractual term, high expectations from the Government and future owners and, not ease and tight construction budget to face imponderables, the management of the company has established the need to require a weekly PPC that at least reaches 85% in monthly average, considering that by obtaining this percentage of compliance, the contractual schedule will also be fulfilled.

Researchers note that showing results graphically causes an immediate positive impact on all participants, and it helped the meeting facilitator to motivate attendees.

RESULTS OF THE LPS IN CJA

During the first 10 weeks, the results obtained in the field after the LPS implementation show that there is a variability in the compliance with commitments and 85% PPC is not achieved until 6th week (Figure 1). This was because practitioners did not have a practical knowledge of the LPS methodology at this stage despite the previous training. An effective Look Ahead was not being performed and constraints were not well identified, and also personnel still had some mistrust and rejection towards the system, which is a situation that leads to uncertainty and noncompliance.

After week 10 the PPC improved, coincident with the strongest stage of the structural work (Figure 1). The tendency of incremental improvement in PPC agrees with most of the prior studies (Ballard, 2000; Fiallo and Revelo, 2002, Junior et al, 1998; Kim and Jang, 2005; AlSehaimi, Tzortzopoulos, and Koskela 2009; Leal and Alarcon 2010). This is mainly due to the fact that after the LPS implementation in the project, all participants have a greater understanding of the methodology. Participants stared identifying constraints for activities that will be perform within 4 weeks regarding safety training, scaffolding installation, materials, and equipment among others. The Look Ahead allowed for better visualization of the constraints and the supervision began to understand that constraints must be monitored in order to release them and improve productivity.

After nearly five months of the LPS implementation, the uncertainty significantly decreased, therefore less variability and better results of the PPC could be observed. This is due to at this stage of the construction work the vast majority of design constraints have already been removed. Moreover, most critical tasks have been performed by company personnel and not by subcontracts, allowing for better control of the construction work progress. In addition, a more mature process is observed of the LPS implementation in the site, as commitments are more reliable and it was possible to perform daily monitoring of constraints for their release.

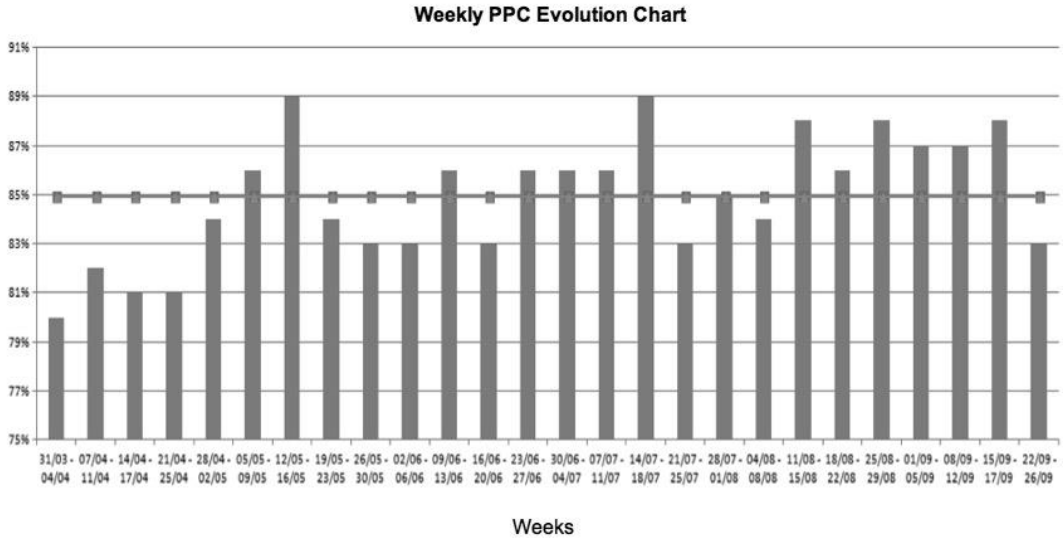

Figure 1: PPC results by week.

Clearly identifying and keeping records of RoN in the LPS implementation allowed for making decisions at the right time. Therefore, mistakes can be corrected protecting the schedule. The RoN helped in defining strategies to address contingencies at the building site, identifying those responsible and ultimately improving construction processes. The practitioners could identify problems with pre-requisites not done, subcontractors, and labor. These 3 RoN were mainly related with lack of labor, due to the market conditions in Chile construction labor was missing, people did not stayed at the work and left without notice. In addition, other improvements were done in material procurement procedures, sales schedules, and treatment of subcontracts.

Figure 2 shows RoN in CJA project. It can be seen that there are several variables that affect the effectiveness of planning, some with more impact than others on the schedule.

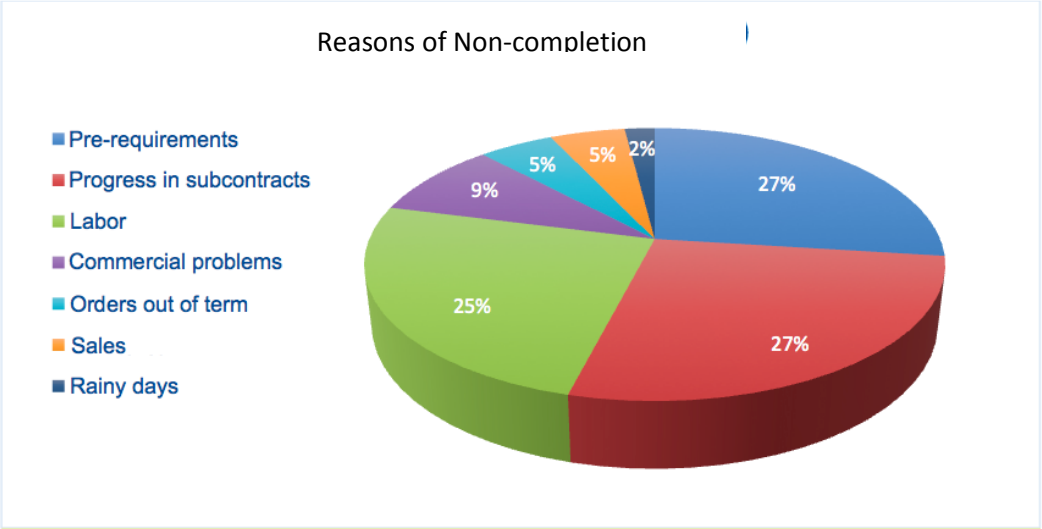

Figure 2: RoN acumulated.

• PROJECT´S PERFORMANCE

Table 1 summarises the results of CJA and previous projects of similar characteristics done previously by Oval Construction Company arranged by year of construction. Early projects did not have implementation of LPS.

Table 1: Projects performance by year of construction.

Work	Year	Amount of apartments	Duration	Profit	Safety	Quality
Portal del Bosque	2010/2011	80	12 months, 25% delay	5%	36 accidents	217 after-sales complaints
Aires del Sur	2011/2013	150	18 months, 50% delay	-2%	47 accidents	285 after-sales complaints

Nuevo Imperio	2011/2013	150	18 months, 50% delay	-3,5%	56 accidents	237 after-sales complaints
Los Almendrales	2012/2013	150	18 months, without delay	12%	14 accidents	47 after-sales complaints
Los Mañíos	2012/2014	184	20 months, 23% in advance	18%	9 accidents	119 after-sales complaints
Bicentenario del Bosque	2013/2014	136	12 months, 20% in advance	17,5%	12 accidents	94 after-sales complaints
Condominio Juanita Aguirre	2014	80	10 months, 17% in advance	18%	0 accidents	25 after-sales complaints

The following sections present the detail results in the CJA project after the implementation of the LPS.

- **SCHEDULE**

Regarding the project construction duration, housing construction works ended within 10 months, which means a 17% early of the contractual period of 12 months. This was due to a well elaborated planning process that focused on meeting goals was in place. The implementation of LPS passed on the Lean philosophy to all employees. Practitioners were actively committing, everyone was involved in the planning of the production system. They understood the importance of agreements reached at the planning meeting, and that everyone is responsible for identifying and releasing constraints in order to improve production.

- **COSTS**

Throughout the construction process, cost was monitored using a monthly Cost Control Box. This project achieved a profit of 18%, which equates to an 80% increase on profit compare to the profit considered on the sales budget. This result is only comparable to the best project undertaken by the company.

- **SAFETY**

The LPS implementation allowed to substantially improve historical safety rates, which translates into a work development without accidents and lost days a very positive scenario for the company confirming that productivity can be achieved with the safety needed to protect the integrity of all construction workers. The accident rate was zero. There were no accidents with lost time. This is an excellent result considering that on this type of projects, there are several activities considered to be critical.

This change can be explain by a paradigm shift by safety specialist and supervisors, before this implementation safety and production where not considered the same, and safety specialist was acting as a consultant outside of the production system, not involved

in the planning, nor identifying constraints. After the implementation of LPS, practitioners included safety constraints in planning every activity.

OWNER SATISFACTION

To collect feedback on the performance and results of the CJA construction work, a survey was conducted to the construction work technical inspection and the customer (Department of Housing and Urban Development). The survey was focused on knowing the opinion of the technical inspection and customer regarding the management made by the OVAL Construction Company on issues related to the compliance with terms, construction quality, quality of the technical project team and job safety at construction sites.

The result shows that there is a the technical inspection and the Department of Housing and Urban Development were very satisfied regarding the management done by OVAL Construction Company in the CJA project. Both inspections agree on qualifying the results obtained as very good (the maximum scale in the survey used) during project construction and consider that the planning was fulfilled. And gave a very good qualification with regards to construction quality, materials used, expertise and response capacity of the professional team during construction, safety management, and relationships with future homeowners.

END USER SATISFACTION

Finally, an opinion poll was conducted to future owners of the CJA, which was of great importance since they represent end customers.

The results show great satisfaction of owners regarding issues such as compliance with scheduled terms, and construction quality.

In addition, after the families moved in they were allowed and encouraged to make after-sales complaints to OVAL Construction Company during the first month, this metric was also historically collected in previous projects. The CJA project had a significant decrease in the number of complaints received. Of course, the size of the project could also have an impact on the result. However, medium and small projects can also have deficient performance.

DISCUSION

The team experienced several barriers to implement the LPS on site. At first, the researcher observed field personnel reluctance when being on a meeting for a long time, as well as unpunctuality and poor preparation for the meeting. Another barrier was that participants in the meeting did not understand why they were assessed weekly. The management had to show to that measuring performance of each participant was essential to measure PPC. Once workers understand the purpose of the measurement, an atmosphere of healthy competition and collaboration is created, because they understand that LPS requires teamwork, and that in order to comply with commitments, they depend on other areas.

The researchers believe that it is essential to train all personnel involved in the planning meeting in order to establish a common language and to introduce the concepts of Lean Construction, besides daily reinforcing the main concepts of LPS. Each of the participants

is important in order to achieve a successful planning and to comply with the schedule. The work team must be essentially composed of skilled personnel with expertise and knowledge according to the tasks to be performed.

A fundamental difference between planning with LPS and the traditional system are the commitments. The personnel of the construction work must understand that the commitment undertaken should be as reliable as possible and planning should be focused on what can be done, taking into account that planned activities are based on the compliance with the schedule.

Another important point is that commitments should be taken as a "mission" and not as a task. The difference is that when planning tasks, the person in charge will worry on fulfilling them at the moment the "ground" or prerequisites are available and only then the resources will be provided to do it. However, when taking it as a "mission", the person in charge should worry on identifying constraints and conduct a monitoring in order to release them. This creates a greater involvement for the personnel and integration of the different areas of construction in order to achieve commitments. Therefore, being pro-active is required when implementing LPS.

In the particular case of the JCA project, a high variability was obtained during the first three months of execution of the project. However, this was diminished as months passed, mainly because planning was improved and commitments acquired were fulfilled. During the following months, variability was stabilized and average PPC over 83% were obtained. These results had a positive impact on the overall progress of the construction work, achieving the programmed timing curve and meeting terms.

JCA construction work began without LPS during the first two months, then the methodology was implemented and once the team work started to learn more and adopt the system, the results were better, managing to finish the structural work on time, which were only a week late. At the finishing stage, LPS allowed to improve the quality of constraints analysis and generating more reliable commitments, which enabled to complete the work within 10 months.

Another important point is the end customer satisfaction including families that inhabit the apartments, who expressed their agreement with the execution. The low number of after-sales complaints received in the project provides evidence of the end-user satisfaction.

The LPS implementation improved results regarding construction quality. This is because when planning in detail, it is possible to observe all elements necessary to do the job right at the first time and decreasing technical inspections rejections and rework.

The LPS implementation improved results in accident rates. This was because when integrating the Health and Safety Specialist of the construction work to the planning meeting, allowed the person to have full knowledge of the tasks to be executed, and also advise the teamwork on the conditions and unsafe acts that may occur during an activity. After implementing LPS, safety is seen as everyone's responsibility. Planning contributed to anticipate possible conditions that could cause an accident, having better control of the task to be executed, and finally identifying all elements of personal protection to be used and properly guiding employees on their use.

It was also very important that the safety specialist adopted commitments during the planning meeting. This greatly improves the relationship with field personnel, who not only

sees this professional as a safety inspector, but as a participant generating optimal conditions for developing field works, safely complying with productivity for workers.

Regarding construction costs, a monthly monitoring was conducted on cost control, which is summarized in a 18% profit, considering that the profit projected for this work was 10%, the profit had an 80% increase. This result is equivalent to one of the best results in the company and invites to move forward in the line of investing on this system in other construction works of the company.

The LPS implementation improved productivity, especially due to when performing the Look-ahead the team was able to better identify constraints and taking the necessary commitments to release them, so the construction can be performed continuosly avoiding obstacles.

CONCLUSIONS

The implementation of LPS in CJA shows multiple benefits, such as reduction of construction time, increase profits, improve safety, and increase quality of the project. In comparison the CJA project is considerably better than previous projects of similar characteristics. The most impressive result is that CJA had 0 accidents compared to 56 accidents on Nuevo Imperio project in 2012. This may be explained by a constant and permanent monitoring of working conditions in LPS meetings, since safety has been considered as a weekly topic, incorporating and delivering responsibilities to the safety specialist, and last planners in all planning meetings.

The implementation of LPS had to overcome several batrriers. Therefore the support of the company's management was crucial for the success of the LPS, due to the need to allocate time and resources to change the traditional way of performing the work on site. The figure of "facilitator" of the system is an essential piece for a successful implementation, as he provides technical support and also led the group, guiding meetings and permanently motivating the team.

The analysis and monitoring of constraints was not only performed during the meetings, but also as a daily task of each of the team members and especially the leader, who should be permanently identifying ad managing constraints.

After a successful LPS implementation, it was possible to obtain better results in the various areas studied. As a result of a more reliable planning, continuous works are obtained, reducing downtimes, timeouts, reworks, rejections by the technical inspection, days lost due to accidents, avoid fines for noncompliance with terms or quality, etc. That is why this system does not only improves planning, but also align the goals of the project with those of the team and company, obtaining better results on different areas.

REFERENCES

Alarcón, L. F. (2008). “Guía para la implementación del sistema del último planificador. ” Santiago, Chile: GEPUC, Universidad Católica de Chile.

AlSehaimi, A. , Tzortzopoulos, P. & Koskela, L. (2009), “Last Planner System: Experiences From Pilot Implementation in the Middle East. In:, Cuperus, Y. & Hirota,

E.H., 17th Annual Conference of the International Group for Lean Construction. Taipei, Taiwan, 15-17 Jul 2009. pp 53-66

Ballard, G. (2000), The Last Planner System of Production Control. Thesis submitted to the Faculty of Engineering of The University of Birmingham for the degree of Doctor of Philosophy, May , 2000.

Ballard, G. (1999), "Improving Work Flow Reliability." In:, 7th Annual Conference of the International Group for Lean Construction.Berkeley, USA, 26-28 Jul 1999. pp 275-286

Fiallo, C. and Revelo, V. (2002). "Applying LPS to a Construction Project: A Case Study in Quito, Equador." Proceedings of the 10th IGLC Conference, Gramado, Brazil.

Ballard, G. & Howell, G.A. (2003), "An Update on Last Planner" In:, 11th Annual Conference of the International Group for Lean Construction. Virginia, USA.

Junior, A., Scola, A., and Conte, A. (1998). "Last Planner as a Site Operations Tool", Proceedings of the 6th IGLC Conference, Guaruja, Sao Paulo, Brazil.

Kim Y. and Jang, J. (2005), "Case Study: application of Last Planner to heavy civil construction in Korea", Proceedings of the 13th IGLC conference, Sydney, Australia.

Leal, M. & Alarcon, L.F. (2010), 'Quantifying Impacts of Last Planner™ Implementation in Industrial Mining Projects' In:, Walsh, K. & Alves, T., 18th Annual Conference of the International Group for Lean Construction. Haifa, Israel, 14-16 Jul 2010. pp 518-527

Sabbatino, D. E. (2011). "Directrices y Recomendaciones para una Buena Implementación del Sistema Last Planner en Proyectos de Edificación en Chile." Santiago de Chile: Facultad de cincias físicas y matemáticas, Universidad de Chile.

Yin, R. K. (2013). Case study research: Design and methods. Sage publications.