Last Planner System as a methodology to increase productivity in medium-sized real estate projects

Last Planner System como metodologia para incrementar la productividad en proyectos inmobiliarios medianos

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Abstract**—**Low predictability in the construction industry is a common problem that can lead to numerous project setbacks and difficulties. Multiple factors are involved, such as weather conditions, material supply, coordination between teams, and changes in client requirements. To address these challenges and improve productivity in construction, several strategies can be implemented, such as the Last Planner system, which can help reduce delays, improve coordination between teams, and optimize workflows in the construction environment. First a literature on the Last Planner system and its fundamental principles. Then, a specific case study was conducted, the results of the research showed that the implementation of the Last Planner system had a positive impact on the efficiency and productivity of construction projects. A significant reduction in delays and waiting times was observed, as well as an improvement in communication and coordination between teams.

Keywords**—**Productivity, Predictability, Last Planner System, Building Construction, Management.

I. INTRODUCTION

Over the years, countries have developed and the construction sector is one of the important factors. New methodologies and materials in the construction industry are transforming the way projects are carried out. These innovations are driving significant improvements in efficiency, sustainability, and building quality. As technology advances and new materials are discovered, industry professionals are adopting more advanced and cutting-edge approaches. New methodologies, such as modular construction, the use of BIM (Building Information Modeling), Lean Construction, and the implementation of digital technologies, are revolutionizing the way projects are planned, designed, and built. These methodologies promote greater collaboration between the different construction stakeholders, optimize resource management, and reduce execution times. The Last Planner System (LPS) is based on the early identification of obstacles and proactive problem-solving. Teams hold regular meetings to review task progress, identify potential delays or difficulties, and take corrective action promptly. This helps to minimize negative impacts on the schedule and keep the project on track [1]. Another key aspect of the Last Planner System is constraint management and uncertainty reduction. Teams focus on identifying potential risks and obstacles and take preventive measures to mitigate them. This makes it possible to anticipate potential problems and maintain a continuous and efficient workflow. Factors that make construction projects unpredictable are design changes and lack of predictability in the production of subcontracted trades. Wise decisions about the use of available resources are not made to develop a system where projects can be managed. The low predictability is evidenced by the low percentage of progress in the physical execution of activities [2]. Predictability plays a crucial role in the productivity of any activity, including construction. When predictability is discussed in this context, it refers to the ability to accurately anticipate and plan the tasks, resources required, and timelines of a project. How predictability affects productivity in construction is explored below:

Efficient planning: Predictability allows for more accurate planning of project activities and tasks.

Adequate allocation of resources: Predictability allows for an adequate allocation of the resources needed to carry out the project. This includes labor, materials, equipment, and any other necessary resources.

Workflow optimization: By knowing task sequences and deadlines in advance, bottlenecks can be identified and interruptions in the construction process can be avoided. This allows for a smoother and more continuous work sequence, which improves overall productivity.

In short, predictability is a key factor in increasing productivity in construction. It allows for proper planning and allocation of resources, reduces uncertainty, optimizes workflow, and fosters team motivation. By anticipating and efficiently managing aspects of the project, greater overall efficiency and performance are achieved.

II. CASE STUDY

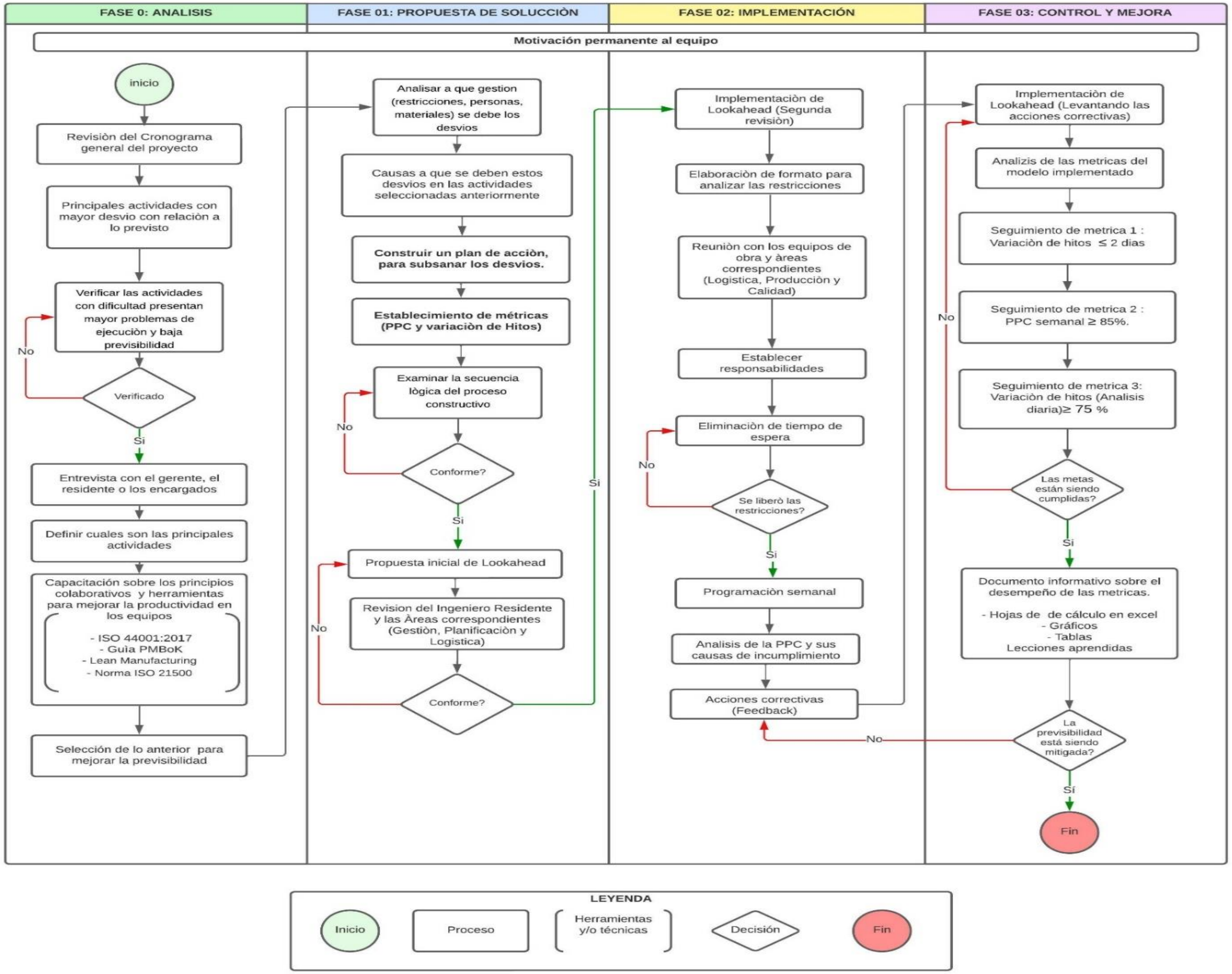
*A. **Data***

The project management method called System Last Planner (LPS) was implemented. This research was implemented in a medium-sized company. The project consists of an apartment building and parking lot with five typical floors and a rooftop terrace. The structure of this building is made of King Kong 18-hole brick masonry walls, reinforced concrete columns, and porticos. It has a 4-meter cistern tank, terrace, living-dining room with balcony, two bedrooms on each floor, and a kitchen, laundry, and 2 bathrooms. In addition, it has an area of 132.9668 m2 approximately and a duration of 7 months.

*B. **Methodology***

In phase zero, an analysis of the project's current situation will be carried out, first by reviewing the project's plans and schedule and obtaining data on the main activities with the greatest deviation from the planned schedule. Subsequently, the Pareto curve will be used to analyze and identify the less predictable items that cause the greatest delay or variation in the work schedule. Then, interviews will be held with the Manager, the Quality Engineer, or those in charge to define which are the main urgent activities that require greater predictability. Once these data are obtained, training on the main collaborators and tools to improve productivity in the teams is carried out [3]. In phase 1, the proposed solution will be developed. First, the constraints, including labor and materials, will be analyzed to determine the possible factors that cause deviations in the progress of the work. Then, once these factors have been identified, an action plan will be developed to correct them. At this stage, the metrics of the model to be implemented will also be established, which will be the PPC (planned percentage completed), the milestone variation, and the TR (required tasks). Subsequently, the logical sequences of the construction process will be examined. Subsequently, the logical sequence of the construction process will be analyzed to understand the correct order of the development of activities. Once these processes are clear, an initial Lookaheads proposal (first version) will be prepared, which will be presented to the resident engineer and the logistics and planning area for evaluation and review [4]. After the approval and correction of the corresponding areas, phase 2 will continue with the implementation of the proposed model. After the second version of the Lookaheads is presented and implemented, a format will be developed to analyze the project's restrictions for 2 weeks. Through meetings with the work teams and corresponding areas, responsibilities will be delegated and established. In this way, we will try to promote collaboration, eliminate waiting times for activities, and lift the restrictions. Once the restrictions have been lifted, we will proceed with the weekly schedule of activities. At the end of the week, the PPC will be analyzed and the causes of non-compliance will be determined. To ensure that the actions and errors that caused the scheduled activities not to be completed on time are not repeated, corrective actions will be proposed. In phase 3, the metrics of the implemented model will be analyzed. For this purpose, it was established as goals that the weekly PPC should be greater than 85%, a milestone variation of less than 2 days, and a milestone variation (daily analysis) ICCAEE 2023 - International Conference on Civil, Architectural and Environmental Engineering Hybrid Event Guangzhou, China, November 17-19, 2023. greater than 75%. If these goals are being met, an informative document on the performance of the metrics will be prepared, which will include summary tables and graphs, as well as lessons learned.

FLOWCHART OF ACTIVITIES FOR THE DEVELOPMENT OF THE ENGINEERING SOLUTION TO IMPROVE PLANNING PRODUCTIVITY IN MEDIUM-SIZED BUILDINGS.



III. Implementation of the Methodology on the Case

In the field of project management, it is essential to have efficient tools and methodologies to plan, control, and improve the execution of tasks and activities. One of these methodologies is the Last Planner system, which has become a reference in the construction industry due to its ability to increase efficiency and reduce project delays [6].

The Last Planner system is based on the collaboration and active participation of all stakeholders involved in the project, from owners and contractors to suppliers and subcontractors. Its main focus is to improve the reliability of planning and execution of activities so that deadlines are met and risks of delays and cost overruns are minimized.

A. Phase 0: Analysis

In the implementation of the model, interviews were conducted with the resident engineer and the quality engineer to identify the items that cause the most delays in a construction project, and that need more and/or better predictability to try to reduce delays and rework in the project. The interviewee provided valuable information on the main items causing delays and their possible causes.

According to those interviewed, the lack of timely delivery of materials is a frequent cause of delays at a construction site. Logistical problems, lack of coordination between suppliers and contractors, as well as delays in the shipment of materials, generate significant delays. They also indicated that the lack of and/or delays in payments by the contractor and subcontractors caused a significant delay in the execution of the project, which was paralyzed for several days. Therefore, prior discussions and constant communication with the contractor and subcontractors should be maintained to avoid this type of delay.

After data collection, a Pareto diagram was drawn up with the main causes that generated delays in the project, as shown in Table I.

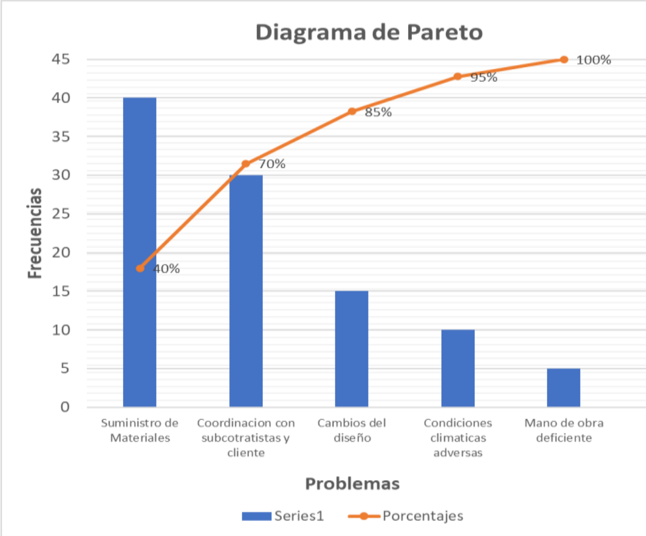
TABLE I. MAIN CAUSES OF PROJECT DELAYS

N°	Principales Problemas	Número de ocurrencias	Porcentaje de Frecuencia	Acumulado
1	Suministro de Materiales	8	40.0%	40%
2	Coordinacion con subcotratistas y cliente	6	30.0%	70%
3	Cambios del diseño	3	15.0%	85%
4	Condiciones climaticas adversas	2	10.0%	95%
5	Mano de obra deficiente	1	5.0%	100%
	Total	**20**	100.0%	

Figure 1 shows the Pareto Diagram of the main causes of delay in the project.

Figure 1

Pareto Diagram



This phase also identified the main activities, shown in Table II, that will be carried out during implementation and which must be taken into account when analyzing the constraints and preparing the Lookahead.

TABLE II. ACTIVITIES DEVELOPED DURING THE IMPLEMENTATION STAGE

ACTIVIDADES
TREN DE ESTRUCTURAS
Acero en columnas
Encofrado de columnas
Concreto en columnas
Acero en vigas
Encofrado de losa
Instalaciones Sanitarias
Instalaciones Electricas
Acero en losa
Encofrado de vigas
Acero en escalera
Encofrado en escalera
Ladrillo de techo
Concreto en losa-vigas-escaleras
Asentado de ladrillos kk
Arquitectura
Tarrajeo
Contrapiso
Lijado y empastado
Pintura

B. Phase 1: Solution proposal

It was reported that suppliers often did not deliver the material on time for the execution of certain activities such as concrete pouring due to factors such as poorly scheduled dates for ready-mix concrete orders or non-compliance on the part of the concrete company.

Establishment of Metrics:

To measure the improvement and development of the implemented model, the metrics of Planned Percentage Completed (PPC), and the variation of Milestones and Tasks Required (TR) were established.

The Planned Percentage Completed will be used to evaluate the progress of the project about the proposed planning and/or scheduling. This metric will allow us to compare the amount of work completed with the work that was planned to be done in a given period.

To carry out this measurement, the Lookahead Planning format will be used to verify the number of activities executed and to obtain the percentage concerning the number of programmed activities. Equation 1 and Equation 2 were used for this purpose.

Equation 1:

PLANNED PERCENTAGE COMPLETED

$$PPC(\%) = \frac{N^\circ\ de\ tareas\ planificadas\ completadas}{N^\circ\ de\ tareas\ planificadas} \times 100$$

Milestone variation refers to changes in the scheduled dates for reaching different milestones or major events in the construction schedule. Milestones will be key reference points that will mark the progress of the project, such as the start of steel erection or the completion+

of bricklaying.

Through the implementation of the TR in the Last Planner system, greater visibility of project progress was achieved and issues and obstacles were identified in real time. This enabled timely decisions to be made and corrective actions to be implemented to minimize delays and ensure that the TR was completed on schedule.

To measure the TR, the following formula will be used, which indicates the required tasks in the percentage of which it has been fulfilled.

Equation 2:

Task required

$$TR(\%) = \frac{N^\circ\ de\ tareas\ planificadas\ completadas}{N^\circ\ de\ tareas\ planificadas} \times 100$$

C. *Phase 02: Implementation*

First, a constraint analysis was performed considering what was stated by the construction teams and the resident engineer [7].

After the constraint analysis, the Lookahead Planning was elaborated and the schedule is for 2 weeks of activities.

After proposing the Lookahead for four weeks, a meeting was held with the corresponding areas to assign responsibilities to the work teams and corresponding areas, to eliminate waiting time and avoid delays in the execution of programmed activities. Likewise, each person responsible for his or her crew was assigned the activities to be performed daily during the week.

After releasing the corresponding restrictions, the first week of implementation was scheduled.

D. *Phase 03: Control and Improvement*

Metrics analysis

1) Planned percentage completed: During the first week of implementation of the model, it was not possible to achieve a PPC of 100%, as shown in Table III, due to two main reasons; the first reason is due to the non-compliance of the ready-mix concrete company; however, the other activities such as slab and staircase formwork, electrical and sanitary installations were completed. The second activity is the second-floor tiling, which was scheduled in the Lookahead because one of the workers did not attend and the expected progress could not be met.

TABLE III. THE PLANNED PERCENTAGE COMPLETED IN THE FIRST WEEK

SEMANA N°	FECHA DE SEMANA	ACTIVIDADES REQUERIDA	ACTIVIDADES COMPLETADA	COMENTARIO	PPC (%)
1	29/05/2023	4	4	se avanzo con el acero de columnas, enconfrado de columnas, concreto de columnas y tarrajeo del primer piso.	100%
	30/05/2023	5	5	Se realizo en total el acero de vigas, encofrado de losa y instalaciones sanitarias y electricas.	100%
	31/05/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	01/06/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	02/06/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	03/06/2023	8	6.5	No se logro colocar el concreto de la losa mas escalera y ademas del tarrajeo del primer piso.	81%

During the second week of model implementation, it was not possible to achieve a PPC of 100%. First, there was a delay in the productivity of the steel reinforcement activities in columns due to the lack of availability of materials (lack of steel for stirrups), since a correct measurement was not performed and the necessary steel for the stirrups was not available. As shown in Table IV.

TABLE IV. PLANNED PERCENTAGE COMPLETED OF THE SECOND WEEK ABLE 4

SEMANA N°	FECHA DE SEMANA	ACTIVIDADES REQUERIDA	ACTIVIDADES COMPLETADA	COMENTARIO	PPC (%)
2	05/06/2023	3	3	se avanzo con el concreto en losa, viga y escaleras, tarrajeo y contrapiso.	100%
	06/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	07/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	08/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	09/06/2023	4	3.5	No se termino de realizar el acero de las columnas. Se avanzo en un porcentaje del acero de columas, encofrado de columnas, y concreto en columnas; tambien, el tarrajeo.	87.5%
	10/06/2023	6	5.5	No se termino de realizar el acero de las columnas, pero si se avanzo con el 75 % de laas columnas; ademas, del tarrajeo del primer piso, e IISS y IIEE.	91.7%

Source: own elaboration

During the second week of model implementation, it was not possible to achieve a PPC of 100%. First, there was a delay in the productivity of the steel reinforcement activities in columns due to the lack of availability of materials (lack of steel for stirrups), since a correct measurement was not performed and the necessary steel for the stirrups was not available. As shown in Table 5.

2) Variation of milestones: Due to non-compliance on the part of the ready-mix concrete supplier, the pouring of the slab and stairs was not carried out on Saturday, so it had to be postponed until Monday, resulting in a delay in the completion of the second level structures phase. Therefore, a milestone variation of one day was generated. Due to the non-compliance by the productivity of the steel reinforcement activities in columns due to lack of availability of materials (lack of steel for stirrups); a correct metering was not performed and the necessary steel for the stirrups was not available). Therefore, a milestone variation of one day was generated, as shown in the table.

3) Task Required (TR): During the week, all of the forecasted activities were completed, except for Saturday, due to non-compliance with the ready-mix concrete supplier and because the personnel was incomplete, as shown in Table V.

Obtaining the results of the task required daily (TR = 81%), and according to one of the established metrics the task required should be greater than 75%; therefore, if the minimum established was met, as shown in the table. During the week, all the predicted activities were carried out, except on Friday and Saturday due to a miscalculation of the steel, as shown in Table VI.

TABLE V. REQUIRED TASK OF THE FIRST WEEK

SEMANA N°	FECHA DE SEMANA	ACTIVIDADES REQUERIDA	ACTIVIDADES COMPLETADA	COMENTARIO	TR (%)
1	29/05/2023	4	4	se avanzo con el acero de columnas, enconfrado de columnas, concreto de columnas y tarrajeo del primer piso.	100%
	30/05/2023	5	5	Se realizo en total el acero de vigas, encofrado de losa y instalaciones sanitarias y electricas.	100%
	31/05/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	01/06/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	02/06/2023	9	9	Se avanzo con el acero de losa, vigas y escaleras, encofrado de losa y escaleras, instalaciones sanitarias; ademas del tarrajeo del primer piso.	100%
	03/06/2023	8	6.5	No se logro colocar el concreto de la losa mas escalera y ademas del tarrajeo del primer piso.	81%

In the second week of implementation, all the activities planned in the schedule were completed, except on Friday and Saturday; since, due to a miscalculation in the steel metrics, the steel and concrete activities in columns were not completed, as shown in Table VI.

Obtaining the results of daily required tasks (TR Friday=87.5% and TR Saturday=91.7%), and according to one of the established metrics, the required task should be greater than 75%; therefore, the minimum established was met, as shown in the table above.

TABLE VI. REQUIRED TASK OF THE SECOND WEEK

SEMANA N°	FECHA DE SEMANA	ACTIVIDADES REQUERIDA	ACTIVIDADES COMPLETADA	COMENTARIO	TR (%)
2	05/06/2023	3	3	se avanzo con el concreto en losa, viga y escaleras, tarrajeo y contrapiso.	100%
	06/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	07/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	08/06/2023	4	4	Se realizo las instalaciones sanitarias y electricas; ademas, asentado de ladrillo y tarrajeo.	100%
	09/06/2023	4	3.5	No se termino de realizar el acero de las columnas. Se avanzo en un porcentaje del acero de columas, encofrado de columnas, y concreto en columnas; tambien, el tarrajeo.	87.5%
	10/06/2023	6	5.5	No se termino de realizar el acero de las columnas, pero si se avanzo con el 75 % de laas columnas; ademas, del tarrajeo del primer piso, e IISS y IIEE.	91.7%

In the last week of implementation, the activities planned in the schedule for each day were fulfilled, since more realistic deadlines were established, and adjusted to the performance observed in the work groups in the previous two weeks. The change of concrete supplier was also reflected, since the slab-pouring activity was carried out normally on Thursday as scheduled in the lookahead, therefore, all the scheduled activities were completed as shown in Table VII.

TABLE VII. REQUIRED TASKS FOR THE THIRD WEEK

SEMANA N°	FECHA DE SEMANA	ACTIVIDADES REQUERIDA	ACTIVIDADES COMPLETADA	COMENTARIO	PPC (%)
3	12/06/2023	6	6	Se concluyó con las actividades de columnas y que involucran el encofrado y concreto	100%
	13/06/2023	5	5	Se continuó con las actividades de II. EE. y II. SS. y se inició las actividades de acero en vigas	100%
	14/06/2023	11	11	Se comenzó con las actividades de acero en losa, escalera, encofrado en vigas y ladrillo de techo	100%
	15/06/2023	9	9	Se concluyeron todas las actividades relacionadas con concreto y acero, tambien se realizó con normalidad el vaciado de la losa	100%
	16/06/2023	4	4	En el cuarto nivel se iniciaron las actividades de II. EE. Y II. SS. tambien se inicio con el asentado de ladrillos kk	100%
	17/06/2023	4	4	Se continuaron con las actividades del dia anterior y tambien se comenzó con la actividad de tarrajeo del tercer nivel	100%

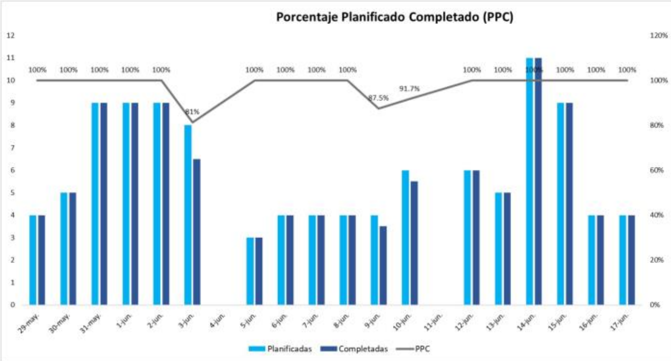
IV. RESULTS

The implementation of the Last Planner system in this specific case has proven to be highly beneficial. It has improved communication and collaboration among the different stakeholders, increased planning reliability, and allowed for greater flexibility and adaptability as changes or unforeseen events arise during project execution.

However, challenges have also been faced during the implementation of the Last Planner system. Some of these challenges include communication between the different areas, and unforeseen situations due to external reasons. In Figure 2, the PPC is shown, making a current and previous comparison.

Figure 2

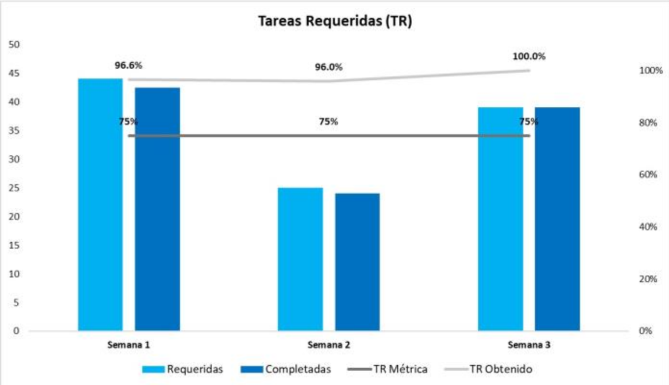
Planned percentage (PPC) of 3 weeks in percentage



The Planned percentage completion of the project before implementing the model was approximately 85% daily. After implementing the engineering solution model, an average daily PPC of 96% was obtained. The main problems of delay and non-compliance of the activities were generated by the lack of material and poor coordination with suppliers. However, in the third week of implementation, a daily PPC of 100% was obtained, as shown in Figure 3, since the performance of the work teams was analyzed and the deadline for delivery of the activities was increased.

Figure 3

3 week task required (TR)



Concerning the Required Tasks, the percentages of 96.6%, 96%, and 100% were obtained for the three weeks respectively; while what was established in the metrics of the proposed flowchart was 75% therefore the minimum percentage was met. This metric reflected the delays generated by the deficient workmanship in the first week because the activity of tiling the walls of the first leveling was not completed.

In the last metric obtained, the variation of milestones in the three weeks of implementation was 1 day in the first week, two days in the second week and finally, there was no variation of milestones in the last week of implementation. Table 11 shows that the second level structures milestone, which concluded with the concrete slab pouring, was initially scheduled for June 3. However, due to non-compliance on the part of the ready-mix concrete supplier, it had to be postponed to Monday, June 5. As shown in Table 12, a variation of milestones was generated in the column steel activity, which in turn meant that the concrete pouring activity for the columns was not completed, since this milestone was initially scheduled to be completed on Saturday, June 17, and had to be postponed to Monday, June 19. However, this metric is within the minimum proposed, which was a variation of milestones less than or equal to two days.

V. CONCLUSIONS

The results of the PPC are higher than what was established in the engineering solution proposal phase, greater than 85%. Although there were unforeseen events on site, such as delays with the concrete company, non-compliance of the workers, or miscalculations of the steel metrics, these did not generate a significant delay in the project since corrective actions were proposed to mitigate the effect of these problems. By analyzing the restrictions of the items and activities for each week, the process was greatly improved; in addition to following Lookahead Planning and thus improving predictability in planning. By analyzing the constraints of each week's items and activities, the process was greatly improved, in addition to following Lookahead Planning and thus improving predictability in planning.

It is important to carry out detailed planning before starting implementation. This clearly defined the objectives, set realistic deadlines, and separated tasks into more manageable stages. This helped to keep all teams and workers on the same track and decrease the delays that were experienced before the implementation of the model. It is necessary to have an early reconnaissance of the project environment before implementation, it is necessary to attend the project at least two days a week to review the inventory of materials and verify that the progress of work is aligned with the schedule, in this way, you can glimpse the possible productivity problems in the planning and take corrective actions to minimize them, reduce uncertainty and variability and to increase predictability. During implementation, there were small delays in the programmed activities due to the lack of constant communication with the material suppliers and workers. In the first case, the company supplying the ready-mix concrete was not confirmed and the slab was not poured on the planned date; in the second case, the wall-tiling activity was not completed because some workers did not attend due to illness. Both cases could have been avoided by holding more regular follow-up meetings to keep everyone updated on progress (concrete supplier) and to address construction equipment problems. Maintaining good control of the materials and supplies needed for the project helps to improve productivity. Proper management of inventories, efficient planning of deliveries, and constant monitoring of material stocks avoid problems of significant delays in milestones such as the one shown in the research work. Poor materials management caused delays and increased project costs since the company supplying the materials had to be changed to reduce the delay. To reduce and/or avoid this type of situation, it is proposed to generate strategic alliances with suppliers, proposing more projects to work together in exchange for meeting the scheduled dates for delivery of materials to the site.

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