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Application of the Lean Construction Methodology in an Urban Paving Work

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Resumen

Con una población creciente, el sector de la construcción se expande continuamente debido a las demandas de la sociedad. Por lo tanto, esta investigación se centró en implementar la metodología de Lean Construction en un proyecto de pavimentación urbana. Esta metodología no experimental se basa en la recolección de datos de campo para mediciones durante tiempos específicos, lo que lleva a resultados cuantificables para el análisis. Antes de implementar esta metodología, el proyecto experimentó retrasos. Sin embargo, con la aplicación de la metodología de Lean Construction y sus herramientas, se lograron los objetivos. La planificación se llevó a cabo utilizando Look Ahead, organizando el flujo de trabajo y logrando un porcentaje de cumplimiento del plan que superó el 70% de los valores proyectados. En consecuencia, se evidenciaron índices de cronograma favorables, superando las proyecciones presupuestarias en los presupuestos ejecutados. La aplicación de la metodología de Lean Construction completó con éxito todo el proyecto dentro del plazo establecido. Además, se observaron mejoras en la productividad y el rendimiento de las cuadrillas en una tarea específica.

Palabras clave: Lean Construction, productividad, porcentaje de plan cumplido, Look Ahead.

Abstract

With a growing population, the construction sector is continually expanding due to societal demands. Hence, this research focused on implementing Lean Construction methodology in an urban pavement project. This non-experimental methodology relies on field data collection for measurements during specific timelines, leading to quantifiable results for analysis. Prior to implementing this methodology, the project experienced delays. However, with the application of Lean Construction methodology and its tools, objectives were successfully achieved. Planning was carried out using Look Ahead, organizing workflow, and achieving a plan fulfillment percentage exceeding 70% of the projected values. Consequently, favorable schedule indices were evident, surpassing budget projections in executed budgets. The application of

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Lean Construction methodology successfully completed the entire project within the set timeframe. Furthermore, productivity and crew performance improvements were observed in a specific task.

Keywords: Lean construction, productivity, percentage of plan completed, Look Ahead.

1 INTRODUCTION

Nowadays, the construction industry is constantly growing to meet people's requests, but with this increase in construction also comes more waste that harms the population and the environment (Naji, Gunduz, and Hamaidi 2022). Conversely, some methodologies, such as Lean Construction, allow for the reduction of this waste. However, not giving it due importance hinders not only the reduction of these wastes but also the performance of small and medium enterprises (SMEs), contractors, and subcontractors who fail to generate added value (Ranadewa, Sandanayake, and Siriwardena 2018). However, given that Lean Construction was adapted to the construction industry, tools and principles have been successfully implemented, but they are often applied inadequately. Additionally, the staff is not familiar or trained with the methodology, which leads to poor results (Von Heyt 2015). Certain factors in the project execution generate negative results, such as deficient management and procedures in construction that result in delays at the beginning of the activities, reprocesses, inefficient planning and programming (Saad Bajjou and Chafi 2019), and the lack of quality in materials and their slow delivery (Gebrehiwet and Luo 2017). On the other hand, low productivity is one of the many challenges faced by the construction industry, which generates delays during the execution of the works (Johari and Jha 2020); therefore, this is the most significant challenge in construction (Kebede and Zhang 2020). Additionally, the Last Planner System is mentioned as a tool that is not being used properly due to certain deficiencies such as the absence of observation, incompatibilities with project delivery methods, inadequate planning, and non-compliance in the analysis of restrictions (Aslam, Gao, and Smith 2020). Therefore, (Xueying et al. 2019) states that applying the Lean Construction methodology has improved management issues related to the speed of project execution and reduced delays (Xueying et al. 2019).

The benefits associated with applying the Lean Construction methodology mentioned by (Babalola, Ibem, and Ezema 2019) are economic, as operating times and costs are reduced, product quality is improved, and inventories are controlled, and social, as work efficiency is increased and good productivity and labor performance are obtained, generating customer satisfaction at the construction site (Babalola, Ibem, and Ezema 2019).

As stated by (Barth et al. 2020), implementing Lean Construction yielded favorable results regarding on-site planning and control; progress was optimal in the work cycles, and a production system database was obtained for monitoring production (Barth et al. 2020). Another favorable case is mentioned by Fullalove, whose study is located in the UK treasuries. By applying Lean Construction, they saved 114 million euros in operating costs. This milestone was achieved by training more than 54 employees at the level of the Highway Agent Foundation (Fullalove 2013).

Regarding the fulfillment of activities by applying the Last Planner System, it states that by analyzing the percentage of plan fulfillment (PPC), the following is related. When productivity is lower, yields increase because resources are poorly used, so this case can be reversed by adequately planning and optimizing resources to increase productivity and obtain positive yields (De La Torre, Taboada, and Picoy 2021). Issa (Issa 2013), in his study PET (percentage of waiting jobs) and PTNT (percentage of unfinished jobs), indicates that these percentages tend to increase when there is no control, i.e., when there are no measurements and planning, these percentages become high, but with the proper implementation of the methodology, they decrease by considerable values (Issa 2013).

Lean Construction is understood as a methodology that conceptualizes the word "value" and gives a whole meaning to the term "waste" (Francis and Thomas 2020). For the Construction Industry Institute (CCI), Lean Construction is defined as the methodology that suppresses waste, reaches to meet customer expectations, oriented to value streams, and obtains fluidity in the works (Li, Fan, and Wu 2019). Poshdar, González, and Kasiviswanatan state that this methodology consists of three essential strategies to increase productivity: decrease in the variability of value flows, fluidity in the work, and optimization of labor performance (Poshdar, González, and Kasiviswanatan 2018). Lean Construction has several tools to meet set goals, including The Planner System, Value Steam Mapping, and Visual Management, among others (Andrews, Erazo-Rondinel, and Huaman-Orosco 2021). With the application of the Last Planner System, it is possible to meet the objectives set. Nevertheless, the following must be considered: master planning,

cooperative projection, anticipated plan, structuring process, weekly work plan, and measurement until the percentage of the plan fulfilled is achieved (Pasquire et al. 2017).

Visual Management is based on the effectiveness of visual communication through attractive visual systems (Tezel et al. 2016), (Tezel, Koskela, and Tzortzopoulos 2013). The key to productivity improvements is not simply to complete the assigned tasks or increase the workload but also to follow the flow of activities, consider decreasing variability and capacity (work time), and to take into account the labor force because these are used to estimate costs, schedules, and planning (Hazim, AbuSalem, and Louzi 2019), (Bamfo-Agyei, Aigbavboa, and Didibhuku 2019).

2 RESEARCH METHODOLOGY

This research is descriptive, because it focuses on events of relevant studies with a non-experimental design since it is based on a timeline, with a population based on the items proposed for the work, of which the samples taken are based on the work performed. Initially, indexed information was collected from databases such as SCOPUS, Scielo, and others to obtain formats and measurement ideas and thus generate a database that allowed analyzing the results that were obtained at the time of executing the activities according to the work items, following up on the activities executed to obtain results to later analyze them with the help of MS Project and Microsoft Excel software.

3 RESULTS AND DISCUSSIONS

At the beginning of this research, the main objective was to analyze the items that would be executed in the work to determine the workflows through Value Stream Mapping. These were identified as rigid pavements, sidewalks, curbs, gutters, retaining walls, signaling, and work cleaning, considering pavements, sidewalks, and gutters as critical points for the completion of the successive activities. The work schedule, as shown in Figure 1, is the master plan to achieve the planning and scheduling of activities, thus leading to the correct reading and data collection of the works to be executed; when the Look Ahead was performed, the Value Stream Mapping allowed to identify the items so we proceeded to sectorize the works, which were given the following denomination: Sector A, Sector B, Sector C, and Sector D; each of these forms a street and a passage.

The measurement of the work progress corresponding to week No. 9 of the execution of the work (before applying the Lean Construction methodology) was made, and the objective was to reach a physical progress of 86.21% equivalent to S/. 511,850. 53, but the executed amount only reached S/. 174,439.48, shown in Figure 2, which is equivalent to a physical state of 29.38%, as shown in Figure 3, which shows a delay of 56.83% in the execution of the work, equivalent to an amount of S/. 337,511.89.

Once the Look Ahead was established, weekly schedules were made, which were followed up with daily schedules. During the study weeks, the following results of the planned works were obtained, which are analyzed through the PPC.

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(a) Construction schedule.

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(b)

Figure 1

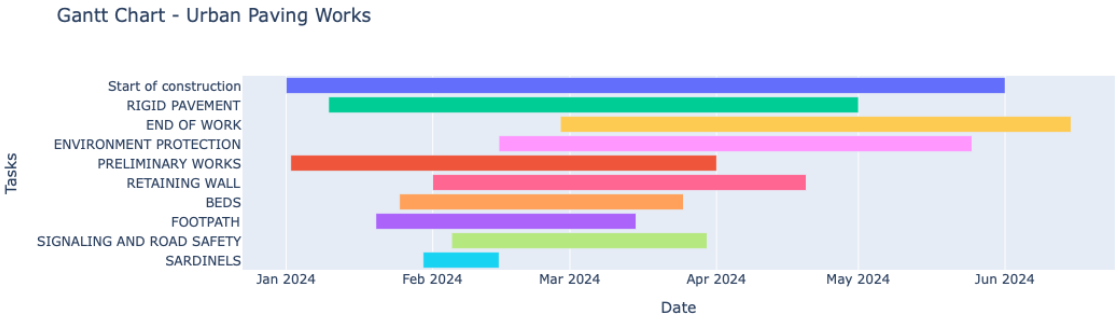

Figure 2: Figura

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Figure 3: S-curve of financial progress of urban paving works.

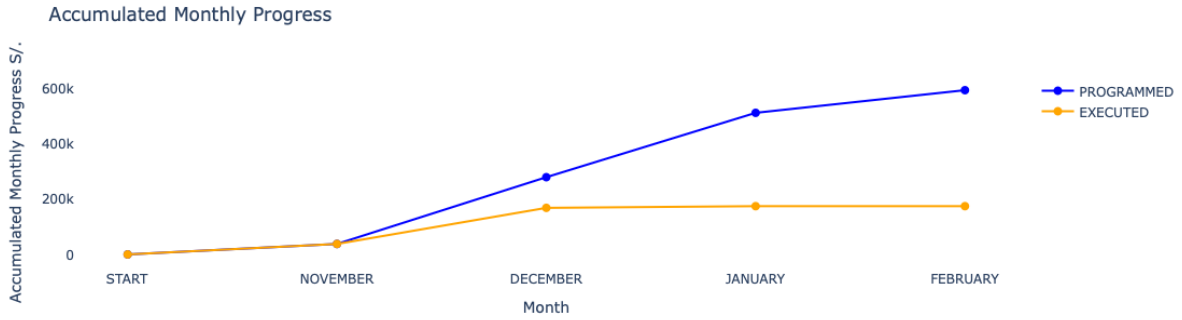

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Figure 5: S-curve of physical progress of urban paving works.

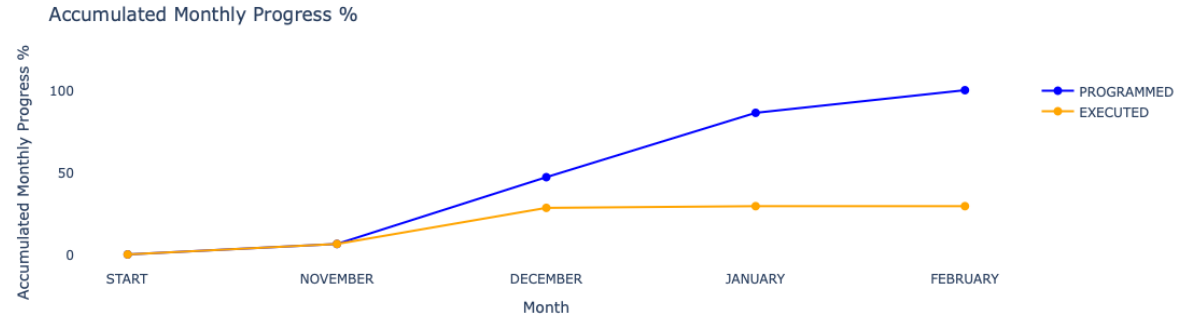

Figure 6: Figura

Figure 4 shows the accumulated PPC in week 10, week 11, week 12, week 13, week 14, week 15 and week 16 were equivalent to 84.21%, 73.77%, 74.86%, 77.57%, 73.44%, 76.47% and 72.22% respectively, showing

that the application of the Last Planner System tool allowed a favorable result, indicating that the work was executed in more than 70% of the projected activities.

Additionally, project management was analyzed using the schedule performance indicator to improve productivity in the urban paving work:

The Schedule Performance Indicator (SPI), as shown in Figure 5, showed the status of the work on the executed budget concerning the projected budget, analyzing the results for the week under study as follows:

If the indicator was less than 1, it indicated a delay as projected that week. However, if the indicator was more significant than 1, it indicated an advance in the projection. From Figure 5, it is visualized that in week 11, week 12, and week 15, there was delay because it was not possible to reach the projected budget, as for weeks 10, week 13, and week 14, favorable results were obtained showing an advance in that week of sampling. Week 16 was equivalent to a week that was completed on time.

Figure 6 illustrates the budget performance over weeks 8 to 16. Weeks 8 and 9 lack values due to the absence of projections. In week 10, the executed budget surpasses the projected budget, with the executed amount being S/. 116,263.67 against the projected S/. 73,314.78, resulting in an earned value of S/. 42,948.89. In week 11, the executed

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Figure 7: Percentage of urban paving work Plan Completed.

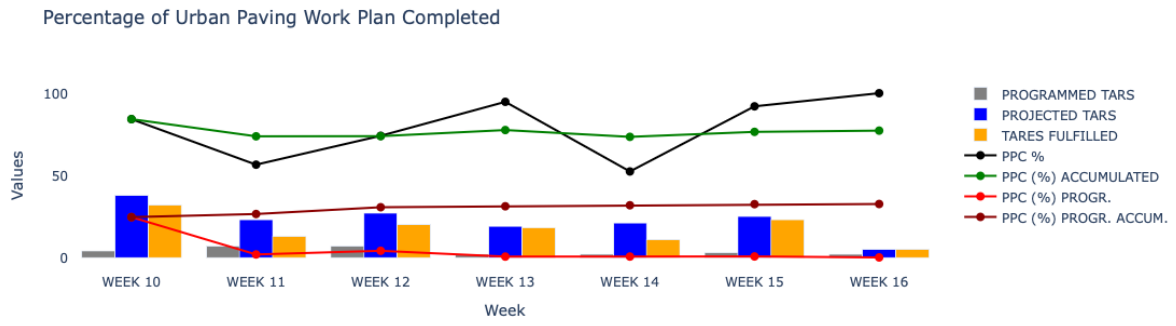

Figure 8: Figura

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Figure 9: Performance indicator in urban paving works.

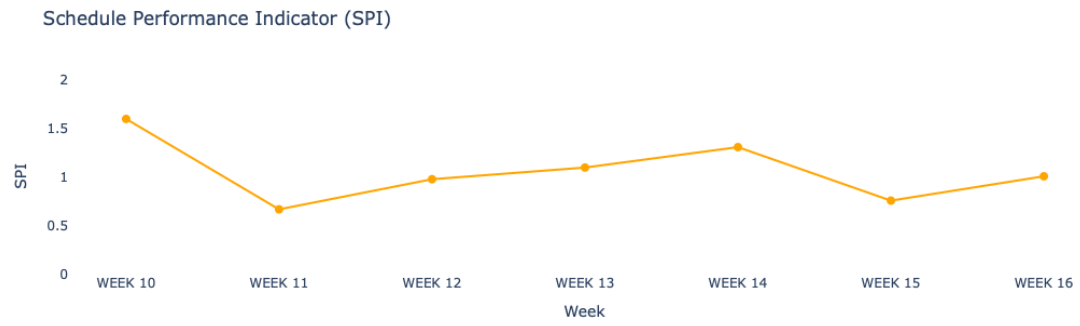

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Figure 11: Comparison of projected value vs. executed value of urban paving works.

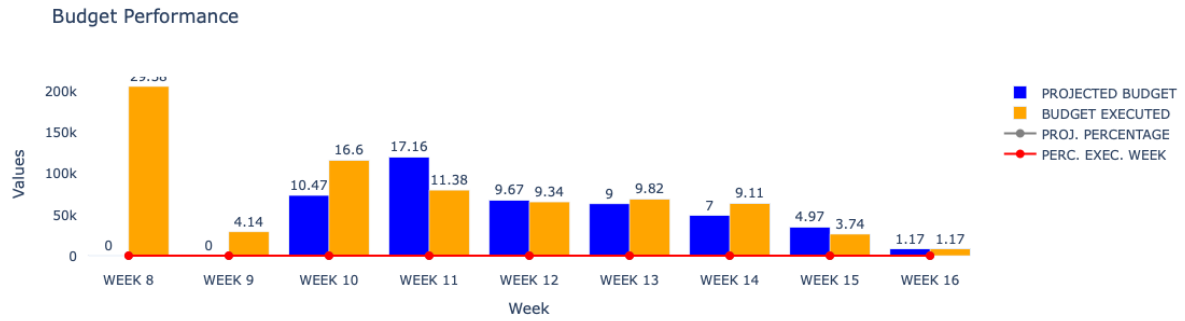

Figure 12: Figura

budget of S/. 79,757.55 falls short of the projected S/. 120,237.24. Week 12 sees the executed budget of S/. 65,402.11 missing the projected goal of S/. 67,760.34. However, in week 13, the executed budget of S/. 68,845.87 exceeds the projected S/. 63,640.70. In week 14, the executed budget of S/. 63,845.87 surpasses the projected S/. 48,035.83. Week 15 shows an executed budget of S/. 26,200.65, below the projected S/. 34,820.82. In week 16, the executed and projected amounts align at S/. 8,202.79.

Figure 7 shows that 100% of the execution was not achieved because the sardinels were not executed in their entirety, which was deducted in a binding deduction. This was not considered in the study until the resolution of the contracting entity was obtained to deduct that amount and thus reach 100% of the execution of the urban paving work. For the month of January, the programmed percentage was not met because when measurements were taken before the methodology was applied, there was a delay in the execution; however, in two weeks, 32.12% of the work was executed. Regarding the productivity analysis, all the items indicated in the urban paving were considered for the project's control. However, for the purposes of this investigation, the item of concrete in gutters was considered, whose measurement began in week 10. It can be seen in Figure 8 that the peaks above the red line indicate that the budgeted productivity was exceeded. In this case, it is observed that this item was not executed for weeks 13 and 14.

Figure 9 shows that optimum yields were obtained. The peaks or points below the red line indicate efficiency and not overexertion in the execution of this item.

Regarding the application of the Lean Construction methodology in this research, it was necessary to

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Figure 13: S-curve - physical up to week 16.

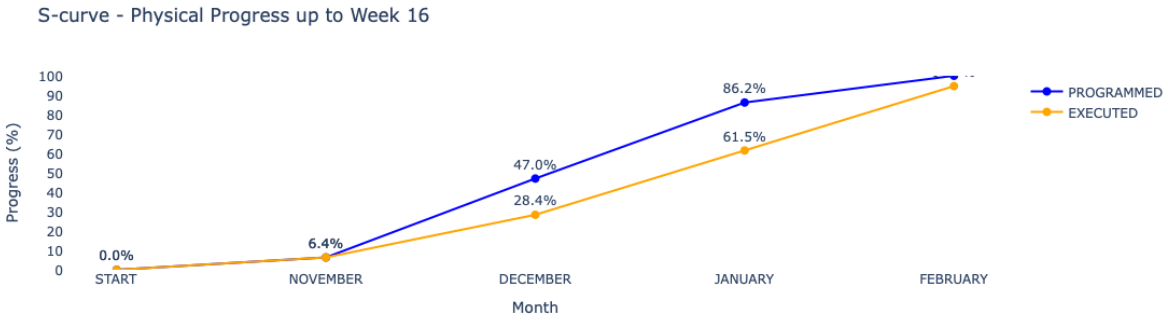

Figure 14: Figura

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Figure 15: Productivity of concrete f'c=175 kg/cm2 in ditches.

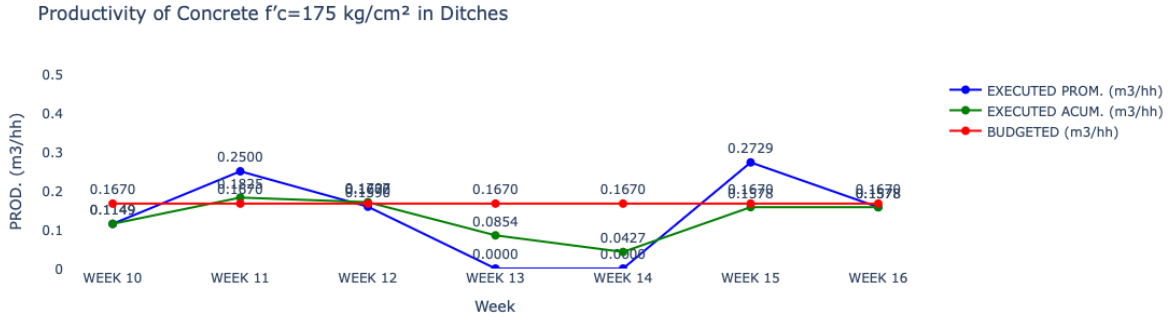

Figure 16: Figura

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Figure 17: Yields of concrete f'c = 175 kg/cm2 in ditches.

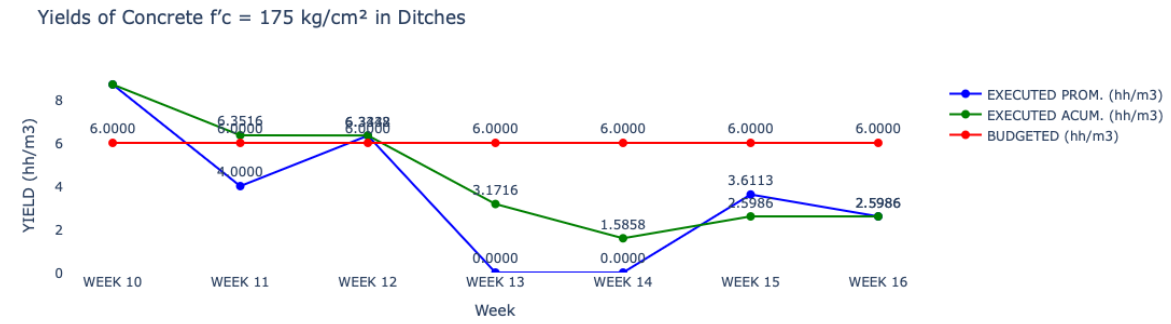

Figure 18: Figura

analyze the work schedule or master plan to identify the critical points and, with it achieve adequate planning and control, agreeing with (Barth et al. 2020), because it was possible to obtain important results such as productivity, monitoring, progress for the execution of the urban paving work, in such

a way that, with the master plan, a more attractive and effective means of visual communication was developed, which is the Look Ahead (Tezel et al. 2016), (Tezel, Koskela, and Tzortzopoulos 2013), differentiating the activities that were to be executed in the proposed work fronts. Since the measurement of the work progress before applying the Lean methodology, it was behind schedule, which was generating financial losses.

Therefore, it was necessary to take action to counteract this situation; consequently, by applying the planning with the projections raised in the Look Ahead, it was possible to reverse the delay in the execution of the project because, thanks to the weekly planning, it was obtained the completed works shown in percentages, that is to say, both the percentage of completed jobs and the percentage of jobs on hold were obtained, showing each week that the minimum percentage of completed activities was 70%, which results in improved productivity and performance, as stated by (De La Torre, Taboada, and Picoy 2021). The percentage of work waiting for the weeks elapsed decreased, which coincides with the results of (Issa 2013).

With the weekly measurements of the work performed, the values gained were visualized as shown in Figure 17, coinciding with what is mentioned by (Xueying et al. 2019) and (Babalola, Ibem, and Ezema 2019) in economic terms, with the completion of the work within the deadline established for its delivery, no penalties were generated. Another favorable aspect of applying Lean Construction was productivity because dead times were reduced; additionally, variability in value flows was counteracted, and good labor performance was obtained, (Hazim, AbuSalem, and Louzi 2019), (Bamfo-Agyei, Aigbavboa, and Didibhuku 2019), (Poshdar, González, and Kasiviswanatan 2018). Indeed, the correct application of Lean Construction contributes to optimal labor performance and to following activity flows considering work times.

4 CONCLUSIONS

This research has shown that the implementation and application of the Lean Construction methodology obtained favorable results for the productivity and execution of the work in urban paving, so it is concluded:

- The application of the tools presented by Lean Construction made it possible to have value streams.
- Through master planning and Look Ahead, the progress of the work was controlled, which from the beginning of its measurement presented a delay of 56.83%, whose result was reverted, reflected in the executed budgets through the projections.
- The PPC was analyzed in the weeks that the methodology was applied, and progress rate of more than 72% per week was obtained, thus obtaining positive, productive results with optimal yields.
- Favorable economic resources and efficiency in the schedules were generated, achieving the objective of improving productivity by applying the Lean Construction methodology, and complying with the projected deadline.

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