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Original Article

Application of the Last Planner System with Earned Value Management: A Case Study from a Road Construction Project in Peru

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Abstract *- This paper examines whether a combined implementation of the Last Planner System (LPS) and Earned Value Management (EVM) improves productivity, schedule adherence, and cost control in a road project started with delays; the aim was to assess if the joint practice of collaborative planning and objective measurement could recover the project schedule, balance weekly production with the accelerated master schedule, and maintain financial efficiency. The methodology integrated pull planning, lookahead planning, and systematic constraint management to enhance the Percent Plan Complete (PPC) and the Constraint Coordination Index (CCI). In the meantime, key performance indicators such as Planned Value (PV), Earned Value (EV), Actual Cost (AC), and their derived metrics (Cost Variance CV, Schedule Variance SV, Cost Performance Index CPI, and Schedule Performance Index SPI) were monitored using the EVM procedure; this integrated measurement system provided advance warnings and guided prompt corrective actions on site; additionally, the results recorded a progressive maturation of plan reliability, expressed in the growing PPC value and the constant reduction of Reasons for Non-Compliance (RNC). Furthermore, schedule performance exceeded the planned values during the first three months and presented values below 1 in the last two months, explained by contractual deductions rather than actual delays. Cost efficiency was also confirmed by a final CPI of 1.03, a positive cost variance of S/ 43,421.06 as an effective saving, and an EV/PV ratio of 97.42%, consistent with the deducted project scope. It is concluded that the integration of LPS and EVM enabled the project to recover, align, and accelerate execution, offering a practical contribution by linking collaborative production control with earned value performance metrics.*

Keywords *- Earned Value Management, Last Planner System, Road Project, Productivity, Resource savings.*

1. Introduction and Background

In Peru, road infrastructure projects face persistent execution problems that have severely affected schedule compliance, costs, quality, and productivity, with frequent cost overruns, project delays, poor coordination among stakeholders, lack of material availability, work stoppages, and low productivity. According to data from the Office of the Comptroller General of the Republic, as of December 30, 2024, there were 2,474 paralyzed projects nationwide, of which 1,782 corresponded to local governments, 308 to regional governments, and 384 to the national government [1]. In many cases, the halted projects had already reached a physical progress equal to or greater than 50%, representing a significant immobilization of resources. In the Cusco region, for example, approximately 250 paralyzed projects were reported, with more than one billion soles immobilized, most under the direct administration of local governments, revealing persistent deficiencies in planning, execution, and monitoring [2].

In this context, there arises a need for methodologies that enhance control, planning, and productivity in the execution of road projects. A promising alternative is the joint application of the Last Planner System (LPS) with Earned Value Management (EVM). The LPS, derived from lean construction, focuses on improving workflow reliability, fostering collaborative planning, identifying constraints early, and ensuring the fulfillment of weekly commitments [3]. The EVM, in turn, integrates scope, time, and cost to objectively measure project performance, anticipate deviations, and support timely corrective decision-making [4]. These methodologies have broad applicability across projects of varying scale and type, from medium- or large-scale roadworks to transport infrastructure, building construction, or service projects, within both municipal and national contexts [5]. Their adaptability allows them to be implemented not only in new projects but also in those experiencing delays or cost overruns to help regain control.

Among the studies related to these methodologies, research conducted by Ramírez A. and Caballero C. [6] in Peru evaluated the estimation of time and cost for the anchored walls of the San Ignacio Hospital, applying three approaches: the traditional method, the Last Planner System (LPS), and the Line of Balance technique; the objective was to investigate the effect of LPS in comparison with traditional planning and the results showed that LPS optimized the execution time by 17%, showing higher efficiency during on-site decision making.

Another study, in fact, was carried out in Peru by Malpica C., Gil L., and Urcia C. [7], which applied the EVM methodology during the execution of housing modules to measure the impact between the planned and executed baselines regarding scope, schedule, and cost; the paper intended to quantify the actual variations with respect to the baseline. It ends with the determination that there is a cost overrun of 8.41% compared to the planned cost, with a real duration of 84 days against 92 scheduled, underlining the usefulness of EVM in detecting deviations and addressing critical points where corrective actions are required.

Alsehaimi A., Tzortzopoulos P., and Koskela L. [8] used action research to implement the Last Planner System in two Saudi Arabian government projects; the aim was to assess the impact of LPS on planning and on-site management. The research concluded that there was improvement in planning, coordination, and communication among stakeholders and overall project management with the use of LPS, but identified barriers such as multiplicity of subcontractors and time-related work habits that had limited its implementation.

A quasi–meta-analysis study was carried out by Rivera L., Baguec H., and Yeom C. [9], in which 25 developing countries, including Korea, were considered for delays in the road construction projects; the analysis aimed at establishing the ranking of the top ten causes of delay in roadworks. The study found that the most significant causes of delays were the inexperience of the construction manager, lack of proper planning and scheduling, and land acquisition problems, followed by faulty communication among project stakeholders, frequent design changes, equipment shortages, and late payment.

Unlike the previous investigations, this research puts into application the synergistic integration of the methodologies LPS and EVM in a specific project entitled: "Improvement and Expansion of Pavements and Sidewalks in the Barrio Centro of Huachocolpa, District of Huachocolpa, Province of Tayacaja – Huancavelica", with Unique Investment Code 2323403. In this respect, the following measurement indicators will be assessed for the Last Planner System: Percent Plan Complete (PPC), Constraint Coordination Index (CCI), and Reasons for Non-compliance (RNC); and the following indicators were evaluated for the Earned Value Management Method: Planned Value (PV), Actual Cost (AC), Earned Value (EV), Schedule Variance (SV), Schedule Performance Index (SPI), Cost Variance (CV), and Cost Performance Index (CPI).

It is expected that from the fifth month onward, the application of the integrated LPS and EVM approach to the road project will enable recovery and improvement in workforce performance, project costs, and schedule delays.

2. Materials and Methods

This research was quantitative and applied, since it was aimed at the resolution of practical problems in project management; its level was descriptive, correlational, and explanatory, while the design was non-experimental, since the variables were analyzed within their natural environment without having been directly manipulated. As presented in Figure 1, the study area was located in the Barrio Centro of the Huachocolpa District, situated in the Huancavelica Department.

The LPS and EVM methodologies were implemented on the evaluated project, whose data are shown in Table 1. The sample consisted of specific project items that were chosen by non-probabilistic convenience sampling because of their greater incidence and the need to represent the most relevant activities aligned with the study objectives; the sample selected consisted of the items corresponding to rigid pavement, sidewalks, curbs, and gutters in the following streets: Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales.

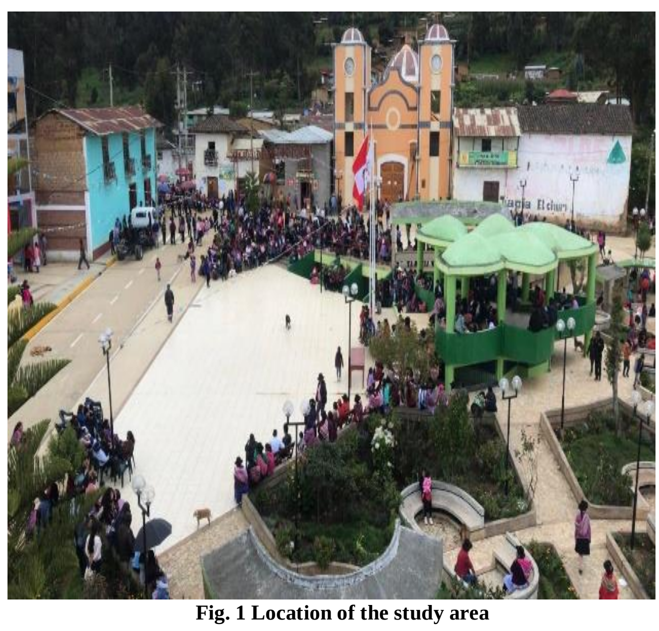

Fig. 1 Location of the study area

Table 1. Project data

Project: "Improvement and Expansion of Pavements and Sidewalks in the Barrio Centro of Huachocolpa, District of Huachocolpa, Province of Tayacaja-Huancavelica"	
Unique Investment Code (CUI)	2323403
Location	Central Neighborhood of Huachocolpa District
Contracting Authority	District Municipality of Huachocolpa
Contractor	Santa Rosa Consortium
Work Supervision	El Carmen Consortium
Awarded Contract Price	S/ 10,013,700.00
Contract Type	Unit prices
Contract Start Date	12/09/2024
Execution Period	240 calendar days
Contract End Date	09/05/2025

2.1. Materials

2.1.1. Constraint Evaluation Sheet

The constraint evaluation sheet is the document by means of which the limitations that affect the continuity of project activities are identified, recorded, and managed, with the aim of having them removed in a timely fashion and complying with the commitments made; this sheet identifies the date on which the control takes place; the type and description of the constraint; the level of impact-whether it is necessary or dependent; the person responsible for removing it; and its status, open or closed. It also makes it possible to document the activities performed and the evaluation of the efficiency of the coordination among the various stakeholders involved in the project. The associated indicator is the Constraint Coordination Index (CCI), calculated as (number of resolved constraints / total number of detected constraints) × 100, which reflects the degree of workflow reliability. According to the Last Planner System (LPS) and the guidelines of the Lean Construction Institute, the early identification and management of constraints are essential steps to ensure that the activities selected in the lookahead planning are ready for execution without interruptions [10]. The model of the Constraint Evaluation Sheet used in the project is presented in Table 2.

Table 2. Constraint evaluation sheet

Restriction List					
Control date	**Restriction**	**Impact level**	**Responsible for releasing it**	**Dates**	**Status**

2.1.2. Weekly Work Plan Sheet

The Weekly Work Plan Sheet is the operational instrument through which the project team defines and records, at the level of "commitments," the tasks that will actually be executed during the week, along with their responsible parties, completion conditions, and identified constraints. This sheet is prepared based on the lookahead plan (2–6 week horizon) to select only activities that are constraint-free and have secured resources.

Within the framework of the Last Planner System (LPS) and following the approach of the Lean Construction Institute (LCI) [11], this sheet materializes the commitment planning (Weekly Work Plan) and serves as the basis for measuring the Percent Plan Complete (PPC) and learning from deviations.

In this study, it was applied to work periods from Monday to Saturday, with 8-hour daily shifts (08:00–12:00 and 13:00–17:00, with a break from 12:00 to 13:00), for a total weekly target of 48 effective hours. The model of the Weekly Work Plan Sheet used in the project is presented in Table 3.

Table 3. Weekly work plan sheet

ID	**Activity**	**Section**	**Mon (Start-End)**	**Tue (Start-End)**	**Wed (Start-End)**	**Thu (Start-End)**	**Fri (Start-End)**	**Sat (Start-End)**	**Sun (Start-End)**

2.1.3. Weekly Plan Compliance Sheet

The Weekly Plan Compliance Sheet is a tool for systematic recording and measurement of the degree of reliability in planning projects; its application consists of the identification of tasks scheduled for the week, filling in their status-according to whether they were completed, in progress, or not started-and calculating the Percent Plan Complete (PPC) at the end of the week by using the formula: PPC = (number of completed tasks / total number of planned tasks) × 100.

This indicator, proposed by the Last Planner System (LPS), enables the effectiveness of the commitments made to be evaluated and forms the basis for the analysis of the Reasons for Non-compliance, providing feedback for continuous improvement in construction projects [10]. The model of the Weekly Plan Compliance Sheet used in the project is presented in Table 4.

Table 4. Weekly plan compliance sheet

Activity ID	
Task	
Week	
Section	
Committed quantity	
Duration	
Status	
Number of completed planned tasks:	
Total number of planned tasks:	
Percentage of planned tasks completed:	
Additional observations:	

2.1.4. Work Evaluation Sheet

It refers to the classification and measurement instrument of on-site observed time, divided according to three categories: productive work, which adds value directly to the task; contributory work, which gives support to production indirectly; and non-contributory work, which represents losses or waste. To apply it, in the sheet were recorded the specific activities developed by each crew within a task, and which served as a basis for the elaboration of the balance chart and the calculation of the percentage of time allocated by each type of activity. This methodology is based on the Lean Construction principles and the Last Planner System (LPS), in that the identification of value-adding activities and waste is essential for the improvement of productivity and planning reliability [10]; the model of the Work Evaluation Sheet used in the project is presented in Table 5.

Table 5. Work evaluation sheet

Work Classification			
Item	**Productive Work**	**Contributory Work**	**Non-Contributory Work**

2.1.5. Reasons for Non-Compliance (RNC) Identification Sheet

The Reasons for Non-Compliance (RNC) Identification Sheet is the tool used to register, categorize, and quantify the reasons why the planned activities within the evaluated work items were not executed as scheduled; this sheet consolidates both the number and the percentage of weekly incidences, allowing the identification of patterns of noncompliance along the project. In this research, the reasons were summarized under six main categories, namely: insufficient performance; lack of resources; equipment failures; coordination deficiencies; design or scope modifications; and unmanaged permits or delays in approvals. This classification is according to the principles of the Last Planner System, which advocates the implementation of a structured analysis of the constraints and Reasons for Non-compliance to provide feedback to planning and enhance the reliability of the weekly commitments [10]. The model of the Reasons for Non-Compliance (RNC) Identification Sheet used in the project is shown in Table 6.

Table 6. Reasons for Non-Compliance (RNC) identification sheet

Identification of the Reasons for Non-Compliance with Activities						
Week No.	**Performance**	**Resources**	**Equipment**	**Coordination**	**Modifications**	**Permits**
Total						
%						

2.2. Research Methodology

The LPS was used to realize the research objective as a collaborative planning and production control tool with the aim of improving the reliability of the weekly commitments and revealing constraints affecting workflow [12]. Complementarily, the EVM methodology allowed for the measurement of project performance in terms of cost and schedule; it is important to mention that the integration of both methodologies had on-site application from the fifth month of execution because, during the fourth valuation month, it became evident that there was a delay of 35.60% in physical progress, representing less than 85% of the scheduled value [13], this condition is used as the pre-intervention baseline for interpreting the subsequent recovery in schedule and cost performance following the integrated application of LPS and EVM. Therefore, from the fifth month until the ninth, the joint implementation of LPS and EVM was done under the accelerated schedule, aiming at recovering productivity levels, so that compliance with the schedule would be ensured.

2.2.1. Last Planner System

The methodology followed by LPS was applied to the road project for the execution of rigid pavements, sidewalks, curbs, and gutters along Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales; the system was implemented starting in January 2025, due to existing project delays. Firstly, it was developed by pull planning based on an accelerated master schedule, with the purpose of rescheduling activities and putting commitments together according to the new logical execution sequence; then, a lookahead plan was prepared in the medium term, in which constraints were found by means of the Constraint Evaluation Sheet, in order to eliminate them in time so that the scheduled work items were feasible. Once the release of such activities, the Weekly Work Plan Sheet was formulated, where the weekly production commitments were established, monitoring the compliance of this plan through the Weekly Plan Compliance Sheet, where the indicator Percent Plan Complete shown in formula (1) was measured, which makes it possible to evaluate the reliability of the planning. The noncompliances were registered and analyzed using the Non-compliance Cause Identification Sheet, which made feedback and continuous learning possible. Based on this information, the Constraint Coordination Index (CCI) was also calculated as shown in formula (2), an indicator that ensures that, at the time of execution, no obstacles linked to missing drawings, permits, materials, equipment, or labor remain [14]. This methodology, supported by the basis of continuous improvement, allowed for more reliable control regarding the project's critical work items and provided objective metrics so that the project could be managed efficiently.

$$PPC = \left(\frac{Completed\ Tasks}{Scheduled\ Tasks}\right)x100 \qquad (1)$$

PPC = Percent Plan Complete (%)

$$CCI = \left(\frac{Released\ Constraints}{Identified\ Constraints}\right)x100 \qquad (2)$$

CCI = Constraint Coordination Index (%)

2.2.2. Earned Value Management

The Earned Value Management (EVM) methodology was also used for the execution of the rigid pavement, sidewalks, curbs, and gutters along Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales, in order to evaluate the cost and time performance objectively. First, the Planned Value was obtained, which corresponds to the budgeted cost of the work scheduled within a certain period of time, given by formula (3); then, the Actual Cost was calculated, which is the actual expense amount that took place at the site. This includes valuations, materials, labor, and indirect costs recorded during the analysis period, represented in formula (4); in the same way, the Earned Value was obtained, which is the value budgeted of the physical progress realized on items of pavement, sidewalks, curbs, and gutters, presented in formula (5). Based on these three fundamental values, performance control indicators are established. For schedule analysis, Schedule Variance is determined, which is the difference between EV and PV, according to formula (6), and the Schedule Performance Index, which is the ratio between the EV and the PV, reflecting time efficiency regarding the master schedule, given by formula (7). For cost analysis, Cost Variance is obtained, which means the difference between EV and AC, according to formula (8), while the Cost Performance Index is the relationship between EV and AC, which is a measure of efficiency in the use of financial resources as given by formula (9); these indicators are an important tool for detecting deviations in cost and time. It delivers objective information for making decisions in a timely and corrective manner in the management of projects [15].

$$PV\ = BAC * \%\ of\ Schedule\ Completed \qquad (3)$$

PV = Planned Value
BAC = Budget at Completion

$$AC\ = \sum (Actual\ Costs\ Incurred\ during\ the\ period) \qquad (4)$$

AC = Actual Cost

$$EV\ = BAC * \%\ of\ Actual\ Work\ Completed \qquad (5)$$

EV = Earned Value
BAC = Budget at Completion

$$\mathrm{SV}\ =\ \mathrm{EV} - \mathrm{PV} \qquad (6)$$

SV = Schedule Variance
EV = Earned Value
PV = Planned Value

$$SPI\ = \frac{EV}{PV} \qquad (7)$$

SPI = Schedule Performance Index
EV = Earned Value
PV = Planned Value

$$CV\ =\ EV - AC \qquad (8)$$

CV = Cost Variance
EV = Earned Value
AC = Actual Cost

$$CPI\ = \frac{EV}{AC} \qquad (9)$$

CPI = Cost Performance Index
EV = Earned Value
AC = Actual Cost

2.2.3. Productivity

Productivity in the project was measured by recording and classifying field activities into Productive Work (PW), Contributory Work (CW), and Non-Contributory Work (NCW) through a Work Evaluation Sheet applied to rigid pavement, sidewalk, curb, and gutter items on Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales. The quantification of the respective PW percentages, CW, and NCW was done through direct observation-work sampling by intervals, which correspond to activities that add value directly to the product, necessary support activities like preparation, internal transport, and brief meetings of coordination, and waste activities, respectively, like waiting for material or equipment, rework, corrections, or unnecessary movements; with these data, some recurrent constraints and idle times were identified and, later, feedback was provided to the lookahead plan and the Constraint Evaluation Sheet for early release. Adjustments in methods and work sequences were made based on these findings, as well as the makeup of new crews or the restructuring of the existing ones by size and qualified personnel, considering actual productivity rates (m² per workday) and observed variability, and the weekly work plan was then rescheduled with released tasks and minimal operational buffers.

Finally, productivity improvement was verified by monitoring the increase in %PW and the reduction in %NCW over consecutive weeks, together with the planning reliability indicators such as the Percent Plan Complete (PPC), thereby closing the continuous improvement cycle inherent to the Last Planner System (LPS).

3. Results and Discussion

The results obtained from the measurement of the Last Planner System (LPS) and Earned Value Management (EVM) methodologies applied to the road project for the execution of rigid pavement, sidewalks, curbs, and gutters along Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales are presented below:

3.1. Last Planner System Method

3.1.1. Constraint Coordination Indices (CCI)

The evaluation of each selected work item in the sample during daily field visits was performed in order to assess the project constraints and analyze overall productivity; Table 7 presents the percentages of the Constraint Coordination Indices obtained through the integration of the Last Planner System and Earned Value Management, starting from January 2025, for project evaluation.

Table 7. Coordination index of presented and resolved constraints

No. Weeks	Restrictions Presented	Resolved Restrictions	CCI (%)
Week 15	12	7	58.33
Week 16	11	7	63.64
Week 17	11	8	72.73
Week 18	10	8	80.00
Week 19	11	8	72.73
Week 20	10	8	80.00
Week 21	10	8	80.00
Week 22	9	7	77.78
Week 23	10	8	80.00
Week 24	8	6	75.00
Week 25	8	7	87.50
Week 26	6	5	83.33
Week 27	4	3	75.00
Week 28	2	2	100.00
Week 29	5	4	80.00
Week 30	3	2	66.67
Week 31	2	2	100.00
Week 32	1	1	100.00

The trend in the CCI between weeks 15 and 32 is gradually favorable, with the continuous rise in the percentage of compliance as the weeks advanced, from 58.33% in week 15 up to 100% in the last weeks, the result points out that the more time the control system is implemented, the better the coordination that could be achieved in solving the constraints. This work is in accordance with Ballard and Howell [16] when saying that the systematic use of LPS reduces variability sources on-site and enhances workflow reliability; also, a progressive reduction in the quantity of constraints presented. This reflects better planning capability, earlier obstacle removal, and creating a more reliable environment for activity execution; these findings are in line with Koskela [17], who states that only the reduction of constraints will make it possible to have significant improvements in productivity and reliability of project processing. Overall, the obtained results confirm the utility of monitoring the CCI weekly as an indicator of the efficacy in collaborative planning and timely decision-making within the management of the road projects.

During the document analysis and the evaluation of the project execution process, the following types of constraints were identified between weeks 15 and 32, as shown in Table 8.

Table 8. Number of constraints according to their typology

Restriction Type	No. Restrictions
Documentation	26
Materials	20
Installations	34
Safety	12
Technical Specifications	20
Labor	21

By analyzing the types of constraints, it is observed that the higest percentage corresponds to installations, 25.56%, which are mainly linked to water and sewer connections, latent in the execution of the sub-items of the project; then come the ones related to documentation, 19.55%, associated with the processing of permits and resolutions linked to delays and complications in progress according to the schedule. This coincides with the statement of the Lean Construction Institute (LCI), which identifies document management as one of the critical points for avoiding stops in projects [12]. In labor matters, 15.79%, where the reduced availability of personnel and inadequate training influenced the time of execution, as well as the quality of the completion of the work. Similarly, material constraints and those of technical specifications stood at 15.04% each, which, on the one hand, reflected delays in the timely supply of materials, and on the other, failure to comply with the established technical specifications, which caused temporary work stoppages. The constraints of safety reached 9.02%, mainly due to the lack of adequate preventive measures and partial compliance with safety protocols increased the risk of incidents, and the corrective measures involved slowed the execution of the works; this is in line with reports from the International Labour Organization (ILO) that indicate the need for more rigid safety systems in construction projects [18].

3.1.2. Percent Plan Complete (PPC)

The PPC results are presented for the rigid pavement, sidewalk, curb, and gutter work items along the Progreso, Augusto Hinostroza, Santa Rosa, Street No. 2, and Los Manantiales roads, obtained through the integration of the Last Planner System and Earned Value Management starting from January 2025.

Table 9. Percent Plan Complete (PPC) of the weekly planning for the rigid pavement work item

No. Weeks	Scheduled Tasks	Completed Tasks	PPC (%)
Week 15	12	10	83.33
Week 16	11	10	90.91
Week 17	14	12	85.71
Week 18	13	12	92.31
Week 19	14	11	78.57
Week 20	11	11	100.00
Week 21	11	9	81.82
Week 22	13	12	92.31
Week 23	11	9	81.82
Week 24	12	9	75.00
Week 25	13	12	92.31
Week 26	10	10	100.00
Week 27	11	10	90.91
Week 28	12	10	83.33
Week 29	10	10	100.00
Week 30	8	8	100.00
Week 31	9	9	100.00
Week 32	8	8	100.00

Table 9 shows the analysis of the PPC of the rigid pavement work item that consists of four sub-items: formwork and stripping of the slab, concrete slab f´c = 210 kg/cm², asphalt joints, and curing of the concrete slab, evaluated from week 15 to week 32, the results reflect a positive evolution in the fulfillment of programmed tasks; the values during the initial months ranged from 78.57% to 92.31%, indicating some early challenges with coordination and system adaptation. The application of LPS in conjunction with the EVM methodology, which allowed for ongoing planning adjustments while concurrently controlling costs and schedules, is responsible for the progressive growth that began in week 29 and reached regular values of 100% in the final weeks, indicating maturity in the project management. Such results confirm Ballard and Tommelein [14], who mention that LPS enhances scheduling reliability due to the removal of constraints at an early stage, and Vargas [15], who states that EVM offers a quantitative framework to measure performance and support corrective decisions.

The overall PPC indicates that the improvement process, associated with the experience of the weekly planning process, was decisive for the accomplishment of the 100% completion of the planned tasks in the final months, reflecting an increasingly efficient management system and aligned with the principles of lean construction.

Table 10. Percent Plan Complete (PPC) of the weekly planning for the sidewalk and curb work items

No. Weeks	Scheduled Tasks	Completed Tasks	PPC (%)
Week 15	13	11	84.62
Week 16	12	11	91.67
Week 17	12	12	100.00
Week 18	13	12	92.31
Week 19	14	13	92.86
Week 20	13	12	92.31
Week 21	14	13	92.86
Week 22	14	12	85.71
Week 23	12	12	100.00
Week 24	13	10	76.92
Week 25	13	13	100.00
Week 26	14	13	92.86
Week 27	14	13	92.86
Week 28	13	13	100.00
Week 29	12	12	100.00
Week 30	12	12	100.00
Week 31	10	10	100.00

Table 10 shows the analysis of PPC for the sidewalk and curb work items, evaluated over 17 weeks; they are divided into four sub-items: formwork and stripping, concrete f’c = 175 kg/cm², asphalt joints, and concrete curing. The results reflect a positive trend that reaches levels of 100% completion, even with some intermediate fluctuations, in the last weeks- e.g., from week 25 to week 31. The lowest value was found in week 24, at 76.92%, which can be explained by previously identified limitations, such as delay in the obtaining of documentation, limitations in material supply, and difficulties in installations that had consequences on the normal completion of scheduled tasks.

However, the upward curve from the successive weeks shows that these limitations were duly managed and solved in a timely manner to enhance continuous improvement and learning among work teams; this behavior confirms the findings of Hamzeh et al. [19], who state that maturity in the application of LPS increases the reliability of weekly planning, and also aligns with Hussain et al. [20], who affirm that the early removal of constraints and stabilization of workflow are key determinants for reaching high levels of task completion in construction projects.

Table 11. Percent Plan Complete (PPC) of the weekly planning for the gutter work item

No. Weeks	Scheduled Tasks	Completed Tasks	PPC (%)
Week 15	8	7	87.50
Week 16	7	7	100.00
Week 17	8	7	87.50
Week 18	8	8	100.00
Week 19	7	7	100.00
Week 20	7	7	100.00
Week 21	8	7	87.50
Week 22	7	7	100.00
Week 23	8	8	100.00
Week 24	6	6	100.00
Week 25	8	7	87.50
Week 26	8	8	100.00
Week 27	7	7	100.00
Week 28	7	7	100.00
Week 29	8	7	87.50
Week 30	8	8	100.00
Week 31	7	7	100.00
Week 32	7	7	100.00

Table 11 shows the analysis of PPC for the gutter work item over 18 weeks of evaluation. The item has the following sub-items: formwork and stripping of the triangular gutter; concrete, f'c = 175 kg/cm²; asphalt joints; and concrete curing. All the results obtained over the weeks analyzed were very efficient, with a percentage varying between 87.50% and 100%. There was a slight decline of 87.50% in weeks 15, 17, 21, 25, and 29 due to minor operational constraints regarding labor availability and coordination in the execution of sub-items, which temporarily affected the completion of all planned tasks.

However, the completion rate was 100% during most weeks (16, 18, 19, 20, 22–24, 26–28, and 30–32), reflecting effective planning control, proper resource allocation, and the consolidated collaboration of team members in their progress; the stable performance described is in line with recent studies indicating that the systematic application of the Last Planner System increases reliability in weekly scheduling, with minimum losses due to non-compliance [19], being consistent with statements in Hasan et al. [21], which point to continuous on-site control and feedback as necessary to keep the level of task completion high in infrastructure projects.

3.1.3. Reasons for Non-Compliance (RNC)

Table 12 shows the analysis of the Reasons for Non-compliance related to the evaluated work items, demonstrating a decreasing behavior during the 18 weeks under study, going from 13 reasons in week 15 to only 2 in week 32, which represents progressive reduction in those factors impeding the fulfillment of the weekly planning; such behavior can be explained by the maturation of collaborative planning and the respective continuous improvement mechanisms which, once implemented, allow for the early identification in due time of the removal of constraints, strengthening thereby the reliability of commitments made by work teams. Indeed, organizational learning and systematic feedback were essential to consolidating a more stable and predictable workflow, in accordance with Ballard and Tommelein [14], who state that the disciplined application of the LPS significantly reduces the Reasons for Non-compliance during the execution of construction projects.

Table 12. Reasons for Non-compliance (RNC) of the evaluated work items

Week No.	Performance	Resources	Equipment	Coordination	Modifications	Permits	Total
Week 15	3	1	3	3	1	2	13
Week 16	2	1	3	2	1	1	10
Week 17	3		2	3		2	10
Week 18	3	1	2		1	1	8
Week 19	3	1		2		2	8
Week 20	2	2	1		1	1	7
Week 21	2			3	1	1	7
Week 22	1	1	2	2	1	2	9
Week 23	2	1				1	4
Week 24	1		2	2			5
Week 25	1	1		1	1	2	6
Week 26	1		1	2		2	6
Week 27	2			1		1	4
Week 28	1	2	1	1	1		6
Week 29	1			1		1	3
Week 30		1	1			1	3
Week 31	1	1				1	3
Week 32				1		1	2

During project execution, several reasons for non-compliance were identified in the weekly planning of the evaluated work items, grouped into six types: performance, resources, equipment, coordination, modifications, and permits. Table 13 shows the RNC analysis according to their typology; from this table, it is observed that the category of highest incidence corresponds to performance, with a proportion of 25.44% of the total, with 29 reasons, which reveals that efficiency in execution is of vital importance so that the works will comply with what was planned weekly. These are followed by coordination and permit management reasons, both with high impacts on the continuity of construction processes, with 21.05% and 19.30%, respectively. On the contrary, the less frequent typology corresponds to modifications, with only 7.02%, which would show that changes to design or technical adjustments had minor impacts on the occurrence of noncompliances. These results agree with the studies of Hamzeh et al. [19], who state that the main sources of non-compliance in the Weekly Plan have to do with human and coordination factors and not with small, technical adjustments.

Table 13. Number of RNCs according to their typology

RNC Type	No. Reasons
Performance	29
Resources	13
Equipment	18
Coordination	24
Modifications	8
Permits	22

3.2. Earned Value Management

3.2.1. Planned Value (PV)

Table 14 shows the PV developed based on the accelerated project schedule, applied from January to May 9, 2025, as a recovery measure to compensate for the delays generated since the beginning of the project in September 2024; this analysis considered only the biggest work items (rigid pavement, sidewalks, curbs, and gutters) to see their performance against the new scheduling strategy. The results show that with the accelerated schedule, most of the valuations are concentrated during the first three months of the year, reaching 90.78% in March cumulatively; this contrasts with the trend of a conventional schedule that would evenly distribute progress over time. This pattern represents the need to intensify resources and efforts in the short term so that contractual deadlines are fulfilled and leaves April and May mainly as consolidation and closing months, with 98.16% and 100% of cumulative PV, respectively.

Consequently, the adopted strategy proves the effectiveness of the accelerated rescheduling approach in not only overcoming previous delays but also in prioritizing critical activities for on-time project completion. This finding supports recent research done by Hamzeh et al. [22], who emphasize that collaborative and flexible approaches in planning should be adopted to address scenarios of high variability in construction projects.

3.2.2. Actual Cost (AC)

The analysis of the cumulative Actual Cost (AC) presented in Table 15 reveals that the project was completed in May with a total expenditure of S/1,717,737.29, equivalent to 95.02% of the total budget (S/1,807,799.58), representing a cost saving of S/ 90,062.29 compared to the contractual budget. Although during the initial phase (January and February) the AC exceeded the PV, indicating higher disbursements to meet the schedule, this trend reversed in the following months, resulting in a favorable financial outcome.

The Actual Cost analysis, which shows the accumulated values presented in Table 15, indicates that the project was completed in May with an AC of S/ 1,717,737.29, equivalent to 95.02% of the total budget (S/1,807,799.58), implying a cost saving of S/ 90,062.29 relative to the contractual budget. In the case where, during the initial period, that is, January and February, AC was above PV, indicating higher disbursements being made for the schedule, the trend reversed in the following months, ending on a very positive financial note.

Table 14. Planned Value (PV) according to the accelerated project schedule

Work Item	January	February	March	April	May
Rigid Pavement	S/ 304,911.85	S/ 314,359.41	S/ 170,955.67	S/ 69,895.64	S/ 24,422.45
Sidewalk	S/ 180,598.69	S/ 32,882.33	S/ 38,257.50	S/ 18,477.56	S/ 1,431.43
Curb	S/ 351,956.13	S/ 75,204.03	S/ 34,005.96	S/ 30,913.52	S/ 2,394.83
Gutter	S/ 106,289.10	S/ 15,430.41	S/ 16,314.65	S/ 14,153.13	S/ 4,945.29
Total	S/ 943,755.77	S/ 437,876.18	S/ 259,533.78	S/ 133,439.85	S/ 33,193.99
Cumulative (PV)	S/ 943,755.77	S/ 1,381,631.96	S/ 1,641,165.74	S/ 1,774,605.59	S/ 1,807,799.58
Cumulative Percentage (%)	52.20%	76.43%	90.78%	98.16%	100.00%

Table 15. Actual Cost (AC) according to the accelerated project schedule

Work Item	January	February	March	April	May
Rigid Pavement	S/ 329,304.80	S/ 289,210.66	S/ 123,088.08	S/ 42,335.30	S/ 19,832.35
Sidewalk	S/ 195,046.59	S/ 30,251.74	S/ 27,545.40	S/ 11,456.09	S/ 2,568.51
Curb	S/ 380,112.62	S/ 69,187.71	S/ 24,484.29	S/ 17,166.38	S/ 2,917.16
Gutter	S/ 114,792.23	S/ 14,195.98	S/ 11,746.55	S/ 8,774.94	S/ 3,719.91
Total	S/ 1,019,256.24	S/ 402,846.09	S/ 186,864.32	S/ 79,732.71	S/ 29,037.93
Cumulative (AC)	S/ 1,019,256.24	S/ 1,422,102.33	S/ 1,608,966.65	S/ 1,688,699.36	S/ 1,717,737.29
Cumulative Percentage (%)	59.34%	82.79%	93.67%	98.31%	100.00%

Table 16. Earned Value (EV) according to the accelerated project schedule

	January	**February**	**March**	**April**	**May**
Actual Progress (%)	20.78%	22.68%	12.34%	4.41%	1.61%
Cumulative Progress (%)	56.38%	79.06%	91.40%	95.81%	97.42%
Cumulative (EV)	S/ 1,019,237.40	S/ 1,429,246.35	S/ 1,652,328.82	S/ 1,732,052.78	S/ 1,761,158.35

Table 17. Schedule Variance (SV) according to the accelerated project schedule

	January	February	March	April	May
Cumulative (EV)	S/ 1,019,237.40	S/ 1,429,246.35	S/ 1,652,328.82	S/ 1,732,052.78	S/ 1,761,158.35
Cumulative (PV)	S/ 943,755.77	S/ 1,381,631.96	S/ 1,641,165.74	S/ 1,774,605.59	S/ 1,807,799.58
SV	S/ 75,481.63	S/ 47,614.39	S/ 11,163.08	-S/ 42,552.81	-S/ 46,641.23

Table 18. Cost Variance (CV) according to the accelerated project schedule

	January	February	March	April	May
Cumulative (EV)	S/ 1,019,237.40	S/ 1,429,246.35	S/ 1,652,328.82	S/ 1,732,052.78	S/ 1,761,158.35
Cumulative (AC)	S/ 1,019,256.24	S/ 1,422,102.33	S/ 1,608,966.65	S/ 1,688,699.36	S/ 1,717,737.29
CV	-S/ 18.84	S/ 7,144.02	S/ 43,362.17	S/ 43,353.42	S/ 43,421.06

Table 19. Cost Performance Index (CPI) according to the accelerated project schedule

	January	February	March	April	May
Cumulative (EV)	1019237.404	1429246.349	1652328.818	1732052.779	1761158.353
Cumulative (AC)	1019256.24	1422102.33	1608966.65	1688699.36	1717737.29
CPI	0.99	1.01	1.03	1.03	1.03

Table 20. Schedule Performance Index (SPI) according to the accelerated project schedule

	January	February	March	April	May
Cumulative (EV)	1019237.404	1429246.349	1652328.818	1732052.779	1761158.353
Cumulative (PV)	943755.7721	1381631.956	1641165.739	1774605.589	1807799.582
SPI	1.08	1.03	1.01	0.98	0.97

3.2.3. Earned Value (EV)

Table 16 shows that the cumulative actual physical progress reached 97.42% in May, with a total Earned Value (EV) of S/ 1,761,158.35. Although this value did not reach 100% of the Planned Value (PV = S/ 1,807,799.58), the difference corresponds to the contractual deductions applied in the agreement, which did not affect the quality or the achievement of the project objectives. When analyzing the monthly behavior of EV compared to PV, it can be observed that during January, February, and March, the project remained ahead of schedule, whereas in April and May, the EV values fell below the PV solely as a result of the deductions, and not due to any delays in execution.

In turn, the relationship between the Earned Value (EV) and the Actual Cost (AC) shows a favorable trend throughout the five-month period, as the EV consistently exceeded the AC, indicating efficiency in the use of resources. In cumulative terms, the EV of S/ 1,761,158.35 compared to the AC of S/ 1,717,737.29 demonstrates that greater value was generated for each sol invested. This difference of S/ 43,421.06 represents an approximate 2.53% saving relative to the actual cost, evidencing efficient performance in both financial and technical terms. This confirms that the project achieved its objectives in scope and quality while optimizing the available resources. Moreover, this result is consistent with the Earned Value Management (EVM) methodology, which not only identifies deviations from the planned schedule but also highlights economic efficiency margins during execution [23, 24].

3.2.4. Schedule Variance (SV)

Table 17 presents the Schedule Variance (SV), calculated as the difference between the Earned Value (EV) and the Planned Value (PV). Positive values were observed during the first three months (S/ 75,481.63 in January, S/ 47,614.39 in February, and S/ 11,163.08 in March), indicating that the project was ahead of the scheduled program. In contrast, negative values were recorded in April (-S/ 42,552.81) and May (-S/ 46,641.23), which could initially be interpreted as delays; however, in this case, they are attributed to the application of contractual deductions within the project schedule, which reduced the Planned Value (PV) and consequently caused the EV to appear lower than the PV, without implying an actual delay in physical progress. Under the Earned Value Management (EVM) framework, the results in Table 17 demonstrate how the SV indicator effectively identifies schedule deviations, although its analysis must consider contractual adjustments, such as deductions, to avoid misinterpretations [25].

3.2.5. Cost Variance (CV)

Table 18 presents the Cost Variance (CV), calculated as the difference between the Earned Value (EV) and the Actual Cost (AC). In January, a slightly negative value of –S/ 18.84 was obtained, reflecting a minimal cost overrun during execution. However, from February to May, the results were positive (S/ 7,144.02; S/ 43,362.17; S/ 43,353.42; and S/ 43,421.06, respectively), indicating that the project was executed with greater efficiency in the use of resources relative to the costs incurred.

The interpretation of this indicator shows that positive CV values represent savings or cost management efficiency, whereas negative values reflect cost overruns. Under the Earned Value Management (EVM) approach, the results in Table 18 demonstrate favorable financial performance and adequate resource control, allowing the conclusion that by the end of the project, a total saving of S/ 43,421.06 was achieved thanks to the application of this management methodology.

3.2.6. Cost Performance Index (CPI)

Table 19 presents the Cost Performance Index (CPI), calculated as the ratio between the Earned Value (EV) and the Actual Cost (AC), an indicator that measures the efficiency in the use of the project's financial resources. In January, a value of 0.99 was obtained, reflecting a slight cost overrun; however, in the following months, the results were greater than 1.00 (1.01 in February and 1.03 from March to May), indicating a more efficient use of the available resources.

The interpretation of this indicator establishes that a CPI greater than 1.00 represents cost savings or efficiency, while a CPI below 1.00 indicates cost overruns. In this case, the final result with a CPI of 1.03 confirms that the project was completed favorably in financial terms, demonstrating that the application of the Earned Value Management (EVM) method enabled effective control and cost optimization throughout the execution phase [26].

3.2.7. Schedule Performance Index (SPI)

Table 20 presents the Schedule Performance Index (SPI), calculated as the ratio between the Earned Value (EV) and the Planned Value (PV), an indicator that measures the project's efficiency in meeting the schedule. During the first three months, the SPI was greater than 1 (1.08 in January, 1.03 in February, and 1.01 in March), reflecting performance ahead of the planned schedule. In contrast, in April and May, the SPI decreased to 0.98 and 0.97, respectively, which could normally be interpreted as a delay; however, this result is explained by the application of contractual deductions in the project schedule, which reduced the Planned Value (PV) and caused the EV to appear lower than the PV, without implying an actual delay in progress. Overall, the index confirms that the project developed favorably, as the Earned Value Management (EVM) method demonstrated that the variation in the last months resulted from contractual adjustments rather than deficiencies in execution [26].

Because the research design is more akin to an applied single-case study that focuses on operational performance recovery than population-level inference, formal hypothesis testing and confidence intervals are not used in this study's statistical inference. Rather, the Last Planner System and Earned Value Management-derived multiple performance indicators exhibit consistent and convergent behavior to mitigate uncertainty. The likelihood that the observed results are due to random variation is decreased by the consistent improvement trends in PPC, CCI, and RNC, as well as the gradual stabilization of SPI and CPI values over successive weeks; however, it is recognized that short-term variations in schedule performance and productivity are a natural part of construction operations, especially under accelerated schedules and late-stage interventions.

3.3. Benchmarking with State-of-the-Art Approaches

Recent international work shows that LPS is increasingly supported by digital visual management solutions, such as digital LPS whiteboards for remote collaboration, and by lean BIM data integration frameworks that connect planning, constraints, and production information; however, these approaches typically require high levels of technological maturity, data interoperability, and organizational readiness, which are not always feasible in public infrastructure projects in developing contexts [27]. Similarly, recent studies extend earned value analysis toward proactive, data-driven decision support and improved forecasting, including IT-enabled or AI-assisted approaches [28]. Relative to these state-of-the-art directions, the unique value of this research is that it demonstrates a low-barrier, field-ready integration of LPS and EVM using standardized routines and dashboards (PPC, CCI, RNC alongside PV, EV, AC, SPI, CPI) to improve schedule reliability and cost control without requiring advanced digital platforms; therefore, it provides a replicable baseline that can later be digitalized or scaled to multi-project environments while preserving the core workflow logic described in current LPS benchmarks.

4. Conclusion

The main finding demonstrates that the integration of the Last Planner System (LPS) with Earned Value Management (EVM) enabled the recovery, alignment, and improvement of progress in the road project when it was already in a delayed state by December. Collaborative planning through pull planning, lookahead, and constraint management increased the weekly reliability of the plan, raised the PPC, and steadily reduced the reasons for non-compliance. At the same time, earned value control provided daily visibility of time and cost performance, guiding timely corrective decisions. The result was physical progress that was successfully realigned with the plan, a final CPI of 1.03, a positive cost variance of S/ 43,421.06 as an effective saving, and a cumulative EV of 97.42% relative to PV, explained by deductions rather than scope non-compliance. This confirms the central hypothesis: the combination of LPS and EVM is an effective alternative for improving productivity, time, and cost in road projects.

The particular goals were reached by proving, through objective metrics, the benefit of both methodologies. The SPI was greater than one during the first months, which characterizes the recovery of the production pace, and decreased in the final months due to schedule deductions, which requires contextualizing the interpretation of the indicator. The CPI remained above one from February until completion, confirming efficient financial management. These findings are according to the literature, which attributes to LPS the stabilization of workflow and to EVM the integrated measurement of performance, showing their synergetic action when applied coordinately both in the field and in the management process.

The study's practical implications are evident: project teams should implement weekly commitment management routines and systematic, traceable constraint removal; these routines should be supported by integrated dashboards that integrate Earned Value Management (EVM) metrics, such as Planned Value (PV), Earned Value (EV), Actual Cost (AC), and their corresponding schedule and cost performance indices, with key indicators from the Last Planner System (LPS), such as Percent Plan Complete (PPC), Constraint Coordination Index (CCI), and Reasons for Non-Compliance (RNC). This study's application to a single road construction project is its main limitation, which limits the statistical generalization of the results; however, this limitation does not imply restricted applicability of the proposed approach; since Earned Value Management (EVM) and the Last Planner System (LPS) are both process-oriented, flexible, and project-type independent, their combined application is not project-specific; their straightforward replication mechanisms, standardized workflows, and structured logic allow for easy adaptation to a variety of construction projects, such as buildings, infrastructure, and industrial works. Since the standardized planning cycles of LPS and the universal performance metrics of EVM enable the integrated system to be implemented across various project sizes, contractual arrangements, and organizational contexts with minimal adjustment, the methodological framework itself is transferable and scalable, even though the empirical evidence is derived from a single case. Future studies should focus on multi-project and multi-sector applications to strengthen external validity and further demonstrate the robustness and generalizability of the proposed integrated framework.

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