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LEAN CONSTRUCTION IMPLEMENTATION IN THE CONSTRUCTION OF AN AIRPORT RUNWAY

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ABSTRACT

This study explores the application of Lean Construction in the expansion and restoration of an airport runway, a project marked by complexities and high demands. The aim of this paper is to address the following research question: "What is the effectiveness of the daily scheduling approach compared to the weekly horizon approach for short-term scheduling in complex and variable infrastructure projects?". To answer this question, an extensive literature review was conducted, anchored in the action research method. It was found that the adoption of daily schedules may be more efficient, as it allows for greater agility in responding to client needs, accommodating constant changes requested by stakeholders, and managing uncertainties inherent in infrastructure projects of this nature. The results highlight significant advances in long-term adherence and project management effectiveness, despite encountered obstacles such as coordination among different stakeholders and adaptation to variabilities. The Percentage of Constraint Removal (PCR) improved by 22% from the start to the end of the project, while maintaining a 93% adherence to the Master Planning.

KEYWORDS

Lean construction, Last Planner® System, variability, constraint analysis, lookahead planning.

INTRODUCTION

It is estimated that in Brazil, there will be an investment of over 10 billion reais in airport infrastructure over the next 30 years (Brazil, 2022). Specifically, for the year 2024, an investment of 3 billion is expected, which would represent an increase of 65% compared to previous years. This scenario of significant investment highlights the necessity and feasibility of applying Lean Construction techniques and the Last Planner System to optimize costs, meet deadlines (Mohan & Iyer, 2005), and ensure operational efficiency (Castillo et al., 2014) in large-scale projects.

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Lean Construction seeks to eliminate waste and maximize the value delivered to the client throughout the construction process (Koskela, 1992). The Last Planner System (LPS), in turn, is a methodology that integrates Lean principles for planning and controlling production in construction (Ballard & Howell, 2004). Both approaches have been successful in various sectors, however, when applied to infrastructure projects, they face specific challenges.

The present article aims to present a case in which Lean Construction and the Last Planner system were applied in an airport pavement project. Therefore, it intends to contribute to the development of Lean methodology in infrastructure projects. Thus, it seeks to answer the following research question: What is the effectiveness of the daily scheduling approach compared to the weekly horizon approach for short-term scheduling in complex and variable infrastructure projects?

LITERATURE REVIEW

For the diagnostic phase of the study, a comprehensive review of articles in the IGLC database was conducted to identify research addressing the challenges encountered in implementing Lean Construction and the Last Planner System (LPS) specifically within airport pavement projects. However, the search conducted on 05/04/2024 yielded no results for the term "Airport Runway". Upon broadening the search to the term "Airport", only seven results were returned. Of these, only one article (Herrera, 2018) directly addressed the challenges, while another (Tribelsky & Sacks, 2010) discussed waste management, emphasizing adaptability as a primary requirement and project issues such as "project overrun". These findings underscore the existing gap in the literature regarding the application of Lean Construction and the Last Planner System in infrastructure projects, as previously highlighted by Formoso et al. (2022) and Kassab et al. (2020).

Faced with this limitation, it was necessary to broaden the scope of the research, considering the similarities between airport pavement projects and complex infrastructure projects. Such projects encounter common challenges, including the presence of multiple stakeholders, varying levels of expertise, underground conditions, and the need for intensive coordination. Therefore, articles addressing the main challenges encountered in complex infrastructure projects were sought, aiming to develop a comprehensive strategy that meets all requirements and empowers the team in adopting the Lean philosophy. Existing literature highlights barriers such as the lack of support from senior management (Demirksen, 2019), communication problems (Opsahl et al., 2015), a lack of common understanding of the project's scope and objectives (Schöttle & Böker, 2023), and cultural resistance from those involved (Wandahl, 2014), were found in the literature.

Throughout the research, not only were the issues highlighted in the literature observed, but also successful aspects in projects. Authors such as Opsahl et al. (2015) emphasize the importance of engaging both employees and clients to ensure effective communication and trust development. Kassab et al. (2020) highlight the significance of maintaining commitment from all involved parties. The recommendations found in the literature were essential in guiding the implementation of Lean Construction and the Last Planner System in the journey presented in this article.

METHOD

This paper presents a methodological approach based on action research to assess the implementation of Lean Construction and the Last Planner System in an airport pavement project. The choice of action research as a method of investigation is grounded in the need for a practical and collaborative approach to solving specific problems in a real-world context (Eden & Huxham, 1996). By involving both researchers and action participants, this method allows for continuous assessment, iterative adjustments, and direct feedback, ensuring a thorough understanding of the implementation of Lean Construction and Last Planner System practices in the project.

The Action Research method is based on five main steps: Diagnosis, conducted during the literature review phase; Action Planning, evidenced in the pre-construction phase with the time location technique; Action taking, basing the work's success on Lean and LPS tools and routines; Evaluating, based on the indicators presented in the Results section; and Specifying learning, discussed in the Conclusion section.

BACKGROUND OF STUDY

PROJECT DESCRIPTION

The project carried out at Ministro Victor Konder Airport in Navegantes, Santa Catarina, Brazil, involved the expansion of the landing strip and the restoration of the existing pavement. Originally measuring 1700 meters in length and 45 meters in width, the runway underwent an extension to 1800 meters towards threshold 25. Additionally, threshold 07 was relocated, and Runway End Safety Areas (RESAs) were implemented at both ends. The runway, primarily composed of flexible pavement and rigid pavement at the ends, was adapted to support higher loads by replacing the flexible pavement with a greater thickness along the runway and widening the existing shoulder.

The scope also included the update of horizontal and vertical signage, lighting for low visibility operations, improvements in the drainage system, and a runway strip. Figure 1 presents a comparison between the existing runway and the proposed runway after the improvements are executed.

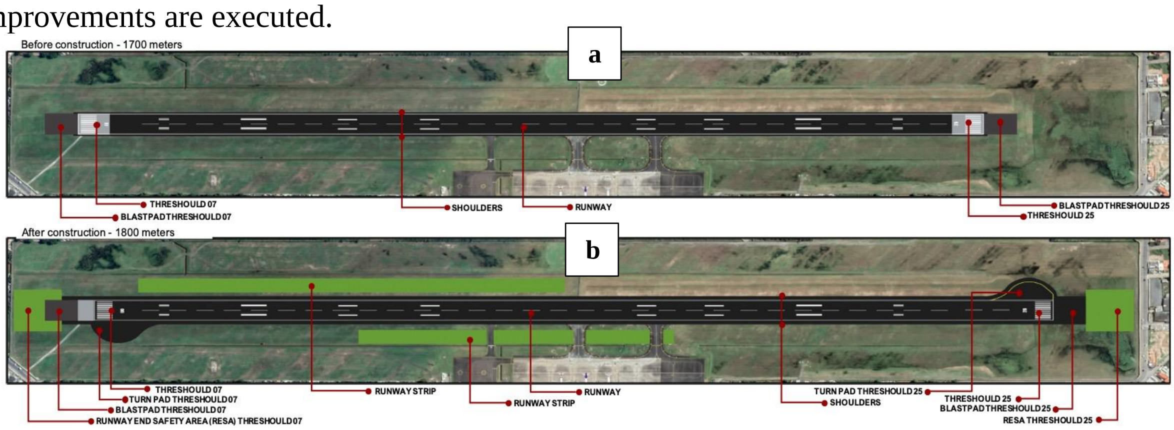

Figure 1: (a) Existing Runway; (b) Runway after the proposed improvements.

LEAN CONSTRUCTION JOURNEY

The Lean Construction implementation journey took place from May to November 2023. An implementation schedule for tools was conceived to introduce Lean Construction principles to project collaborators, as well as their practical application, monitoring, and continuous improvement. Figure 2 presents the timeline of Lean implementation in the Navegantes International Airport project.

In the first month the journey began with the execution of mobilization planning and priority plan studies. In the second month, the Last Planner System (LPS) was applied, integrating planning horizons and visual management tools, which were sustained throughout the entire project. In the third month, emphasis was placed on training and interactive activities about Takt Planning and focus on lessons learned and kaizens, more specifically on the definitive accreditation of collaborators and equipment. In the final months of implementation (four to seven) efforts were made for Pull Planning of drainage and lighting systems and detailed planning of micro-activities and commissioning.

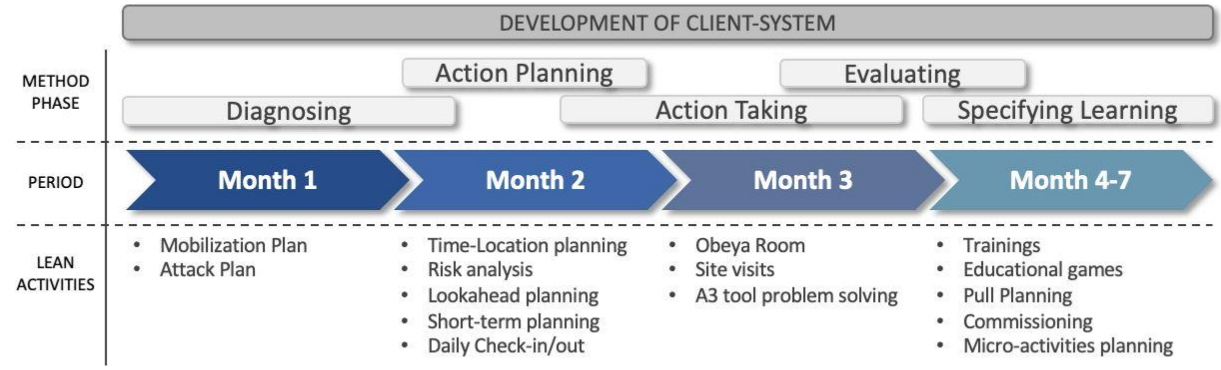

Figure 2: Timeline for LC implementation in the airport project

LEAN CONSTRUCTION IMPLEMENTATION

MONTH 1 – PRE WORKS

From the outset, the project was shown to be of high complexity due to the urgent need for mobilization to meet the contractual milestone with the client. Thus, a swimlane diagram was developed to map all activities (arranged chronologically) to be undertaken by the involved sectors (separated into lanes). These activities ranged from documentation and hiring of collaborators to the establishment of temporary facilities on site. This visual tool delineates the distribution of tasks and facilitates synchronized teamwork, ensuring transparency and cooperation among sectors, as demonstrated in Figure 3.

Figure 3: Swimlane diagram of activities for team mobilization; (a) routine execution; (b) final board

Simultaneously, a priority plan was developed aiming to establish a logical and efficient sequence of activities, with strategic allocation of resources to maximize productivity and reduce waste. This attack plan was developed using the Time-Location methodology to preliminarily map the temporal sequence and location of macro activities, offering clarity in understanding the project flow and facilitating the identification of potential conflicts and overlaps.

MONTH 2– LPS AND VM IMPLEMENTATION

The main challenge of the project was related to the restricted work window from 11:30 PM to 5:30 AM, due to the airport runway's operation during opposite hours. Any delay in production could interfere with the airport operations, making team efficiency a challenge due to time constraints and the need for daily mobilization to the airside of the airport. Recognizing that standard productivity rates in road projects would not be directly applicable in this scenario, studies of daily activities were necessary, focusing specifically on Hot Mix Asphalt (HMA) resurfacing service. The project demanded the application of HMA with different mixes and thicknesses, each presenting its own demands and challenges. Through scheduling scenarios, it was possible to identify an estimated daily productivity, considering time constraints and the processes of mobilization and demobilization. Figure 4 illustrates a pessimistic scenario of the daily schedule for asphalt resurfacing, considering the time constraints due to the continuous operation of the airport runway during opposite hours.

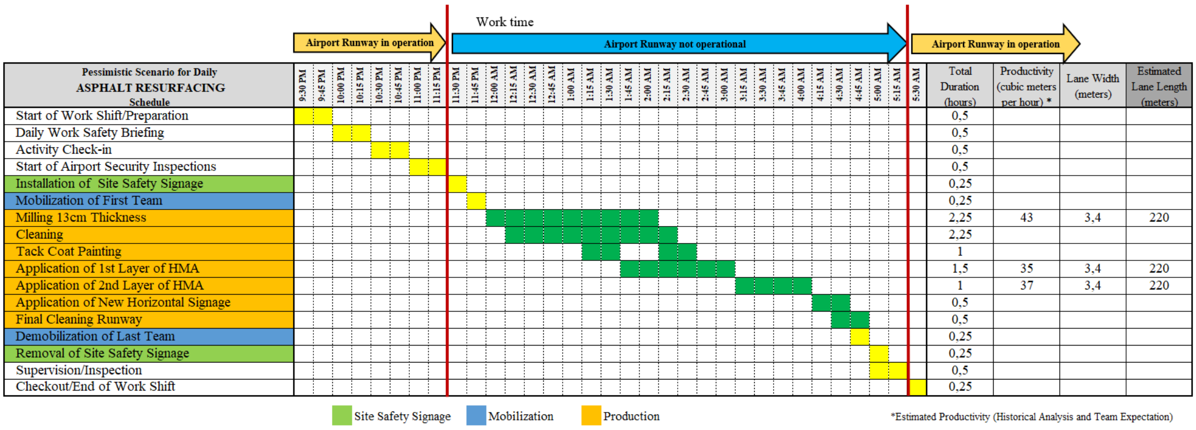

Figure 4: Daily schedule for asphalt resurfacing: pessimistic scenario

A workshop focused on risk identification was also conducted. This collaborative workshop allowed for the mapping of potential uncertainties, which, combined with the daily variation in productivity, was essential for constructing the master plan in a time-location format, integrating buffers into the schedule, and creating scenarios varying according to the identified risks and challenges. The strategy involved setting up macro work packages, as any service initiated had to be completed the same night. This master schedule was posted on the big room wall, as shown in Figure 5, to facilitate the visualization of the proposed attack plan by collaborators.

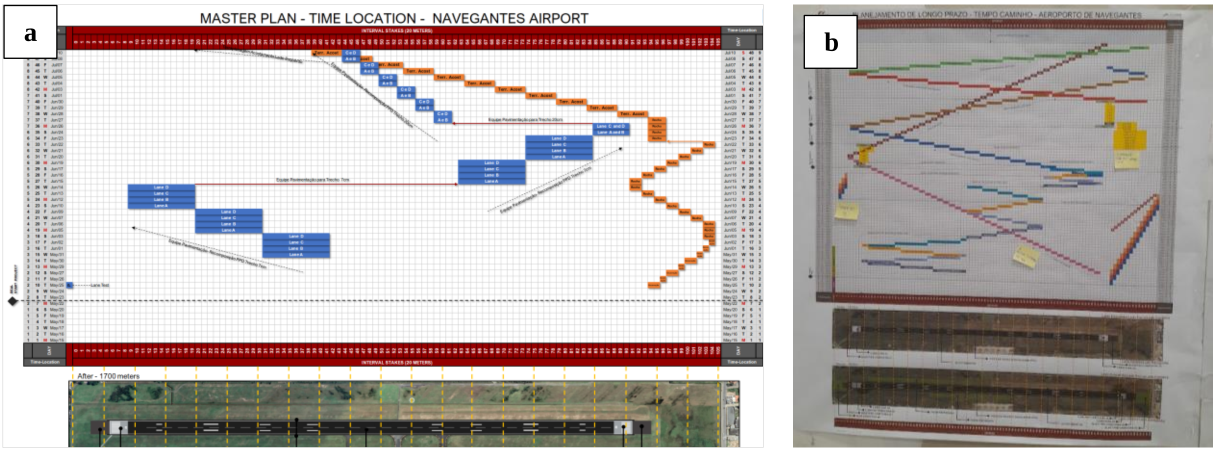

Figure 5: Time-Location master planning: (a) digital version; (b) printed version.

Within the implementation of LPS as a planning and production control system, medium-term, short-term, and learning dimensions were implemented, here represented by the Check-in/out routines as proposed by Ballard & Tommelein (2021). The Lookahead Planning was implemented with a six-week horizon, aiming for proactive identification of constraints and the generation of effective action plans to ensure uninterrupted workflows. From this medium-term routine, the Percentage of Constraint Removal (PCR) indicator was collected. The short-term, developed weekly in collaboration with production leaders, included the weekly activity plan. In this routine, the Percentage of Plans Completed (PPC) and adherence to production in quantity produced were collected. For daily control, daily check-in/out meetings were held for continuous monitoring of progress against the weekly plan, allowing for agile identification of deviations and interruptions for workflow efficiency.

These indicators, along with those developed with other sectors, were continuously presented in the Big Room or Obeya Room once a week for weekly performance evaluation, allowing the team to identify and prioritize the most critical issues. This approach enabled an improvement in collaboration between sectors, strengthening the support chain and its effective communication. All these control mechanisms were implemented due to the unique nature of this project, with constant plan changes from the client, continuity of Airport use during the day, and high variability of thickness with the removal of the asphalt layer. Figure 6 presents the high level of engagement and collaboration across all planning levels.

Figure 6: LPS meetings: (a) Lookahead planning; (b) Short-term planning; (c) Daily Check in/out

MONTH 3 – LESSONS LEARNED AND KAIZEN

Due to the expiration of the temporary accreditation deadline given by the airport administrator to the company, the definitive accreditation of collaborators and equipment became the main reason for the non-completion of scheduled activities. The critical period occurred between weeks 3 to 6, during which there was a peak in expirations resulting in up to 24% of workers being unavailable, as shown in Figure 7. This situation became particularly problematic because the unavailability of key operators from work fronts, such as paving, hindered the progression of activities.

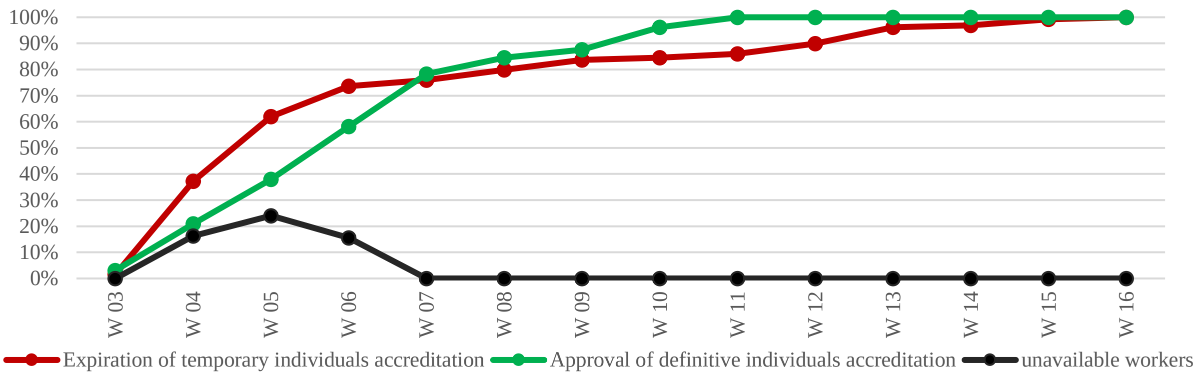

Figure 7: Expirations and Approvals of individual accreditation

Faced with the challenges of the temporary accreditation expiration and the subsequent need for definitive accreditation, the project team adopted proactive measures in August and September. The focus was directed towards training in problem-solving and the effective use of the A3 Tool for analysis and communication. This effort aimed not only to address the immediate issue of accreditation but also to strengthen the team's capacity to deal with future operational challenges. The client's uncertainty regarding accreditation processes exacerbated the situation, highlighting the need for a clear and effective action plan. To mitigate the negative impacts and optimize the accreditation process for the future, a detailed flowchart was developed, as shown in Figure 8, serving as an essential guide to simplify and expedite the accreditation procedure, demonstrating the commitment to continuous improvement and operational efficiency in the challenging context of airport projects.

Figure 8: Process mapping for individuals and vehicles airport accreditation: (a) digital version; (b) printed version.

MONTH 4 – 7 – PULL PLANNING SESSIONS

As the final step in the implementation of LPS, Pull Planning Workshops were conducted for training alongside third-party teams to study activities that were further removed from the long-term schedule. This approach involved teams responsible for the execution, aiming to map necessary tasks and their dependencies, identifying milestones, and establishing a logical sequence of activities to ensure efficiency in the workflow and meet the project deadline. In November, in the final phase, detailed planning of micro-activities focused on delivery and commissioning, tailored for the last three weeks. This meticulous elaboration ensured the identification, planning, and execution of critical tasks, guaranteeing an effective final inspection and the successful completion of the project. This slightly more detailed focus may deviate from the level of detail portrayed by the LPS literature, yet demonstrates that for this type of work, with high variability, it may be necessary to review the short-term planning horizon in order to enhance the predictability of service fronts.

DISCUSSION AND RESULTS

CHALLENGES DURING IMPLEMENTATION

Among the main challenges faced during the Lean Construction (LC) and Last Planner System (LPS) implementation journey, two stand out: the low performance of the Percentage of Constraint Removal (PCR) indicator and the low performance of the Percentage of Plans Concluded (PPC). Regarding the PCR, an average indicator of 54% was observed over the first 3 months of the project (June to August), a number also noted by Jang & Kim (2007) and Torre et al. (2021) in paving projects. This result can be explained by the various changes in the daily execution plan by the client. Despite the high climatic variability inherent to the region where the Airport is located, the change of plan corresponded to 22% of the reasons for non-completion of the week's activities, as presented in Figure 9. Such plan changes also led to an increase in the complexity of the service front (11%) and the lack of projects (10%), as there was not enough time for the prior study of the service front and the execution of the project. These difficulties are corroborated by Demirksen et al. (2019) who identified the main challenge for effective Lean implementation as the communication barrier among stakeholders, whether it be the difficulty in engaging the client or even the lack of effective information sharing and an integrated control of changes.

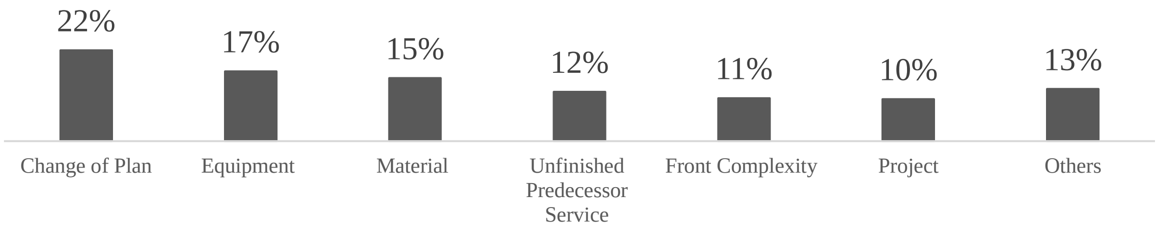

Figure 9: Main causes of interferences in the activities

This change of plan also resulted in not having enough time to identify and solve constraints in time. During the implementation, it was found that 69% of action plans in the lookahead planning were scheduled for the week following the identification date, as shown in Figure 10, indicating a challenge in effectively anticipating constraints. The six-week anticipation strategy, although implemented, proved to be potentially inadequate due to the high level of project uncertainties.

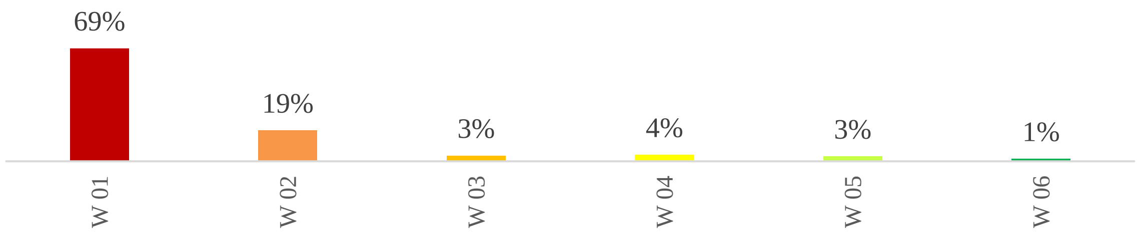

Figure 10: Average time of constraint identification in the lookahead planning routine

In light of this scenario, efforts were made to involve the client in the weekly lookahead planning meetings held in the Big Room. The room and the periodic meetings played a key role in engaging the client due to the transparency and visual management of the main pains felt by the service fronts. Thus, from month 5, a 22% improvement in the PCR indicator was noted, as shown in Figure 11.

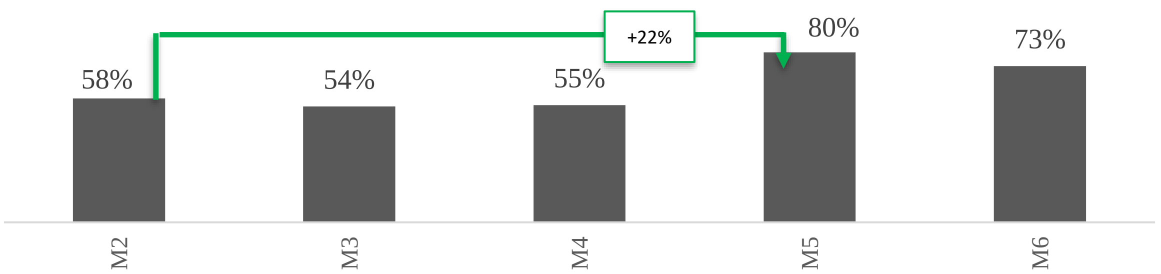

Figure 11: Monthly average PCR

Despite the correlation between PCR and PPC cited by Torre et al. (2021), the PPC did not follow the expected evolution, remaining at 41%, below the average found in the literature for paving works, namely 64% (Torre et al., 2021), 67% (Jang & Kim, 2007), and even 85% (Tezel et al., 2016). As mentioned earlier, most of the causes of non-completion are presented in the change of plan, demonstrating the high variability of the project.

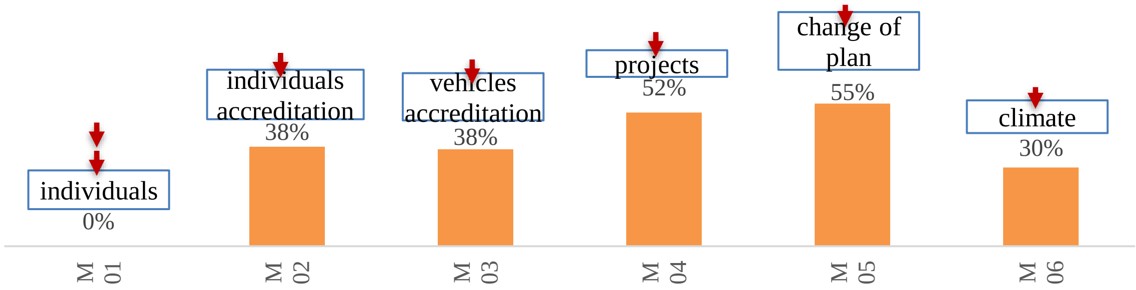

Figure 12: Weekly average PPC and problems

The low PPC indicator itself, coupled with satisfactory adherence to long-term planning, affected team morale. Therefore, a collection of weekly adherence based on the total quantity produced per day was initiated, which ended up raising team morale and maintaining satisfactory performance throughout the project. This adherence indicator showed an average performance of 75% throughout the project and also had an apparent correlation with the PCR indicator, as demonstrated in Figure 13.

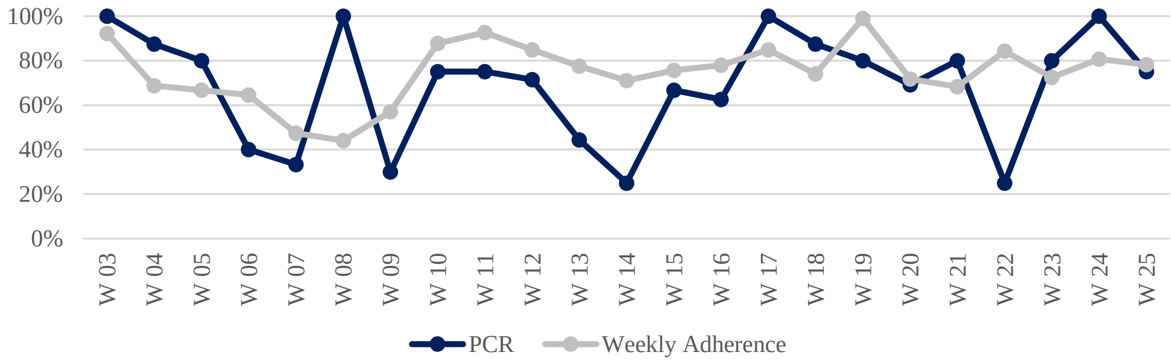

Figure 13: PCR and Weekly Adherence

OVERALL INDICATORS

Overall, the project was successful in the main long-term indicators, achieving 93% adherence to the planned long-term schedule and staying ahead of schedule in 27 of 29 project weeks. During the project, delays were identified only in weeks 2 and 9, with airport accreditation being pointed out as the main cause of these delays. However, the recovery plan effectively brought the project back on track after just one week. Week 21 marked the maximum advancement of the project, reaching 9% ahead of the planned schedule, as shown in Figure 14.

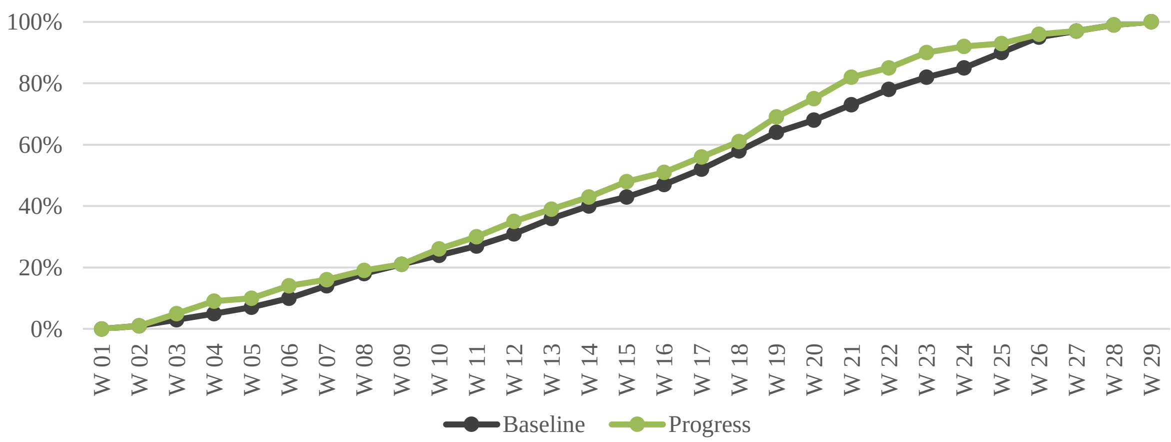

Figure 14: Physical progress chart of the project

CONCLUSIONS

The application of Lean Construction principles in an airport runway expansion and resurfacing project demonstrated significant improvements in schedule adherence and operational efficiency. The integration of strategies such as the Last Planner System and Pull Planning, complemented by visual management tools and collaborative work, resulted in more agile and adaptable project execution. Overcoming challenges such as accreditation constraints and climate variations highlights the importance of flexible planning and rapid response. The success achieved, marked by significant progress in scheduling and reduced variability in constraint removal, reinforces the value of Lean Construction in optimizing complex projects and promoting a culture of continuous improvement.

Analyzing the challenges faced during the project implementation, such as the low Percentage of Constraint Removal (PCR) and the Percentage of Complete Plan (PPC), resulting from low client engagement in routines, frequent plan changes, uncertainties related to accreditation, and local climate variations, questions the effectiveness of the weekly horizon approach for short-term scheduling in projects characterized by high complexity and variability, as addressed in this study. The analysis of the various stages developed over seven months addresses the research question proposed in this study, since that the adoption of daily schedules may be more efficient, as it better adjusts to the agility required by the client, considering the constant changes requested by all stakeholders and the uncertainties inherent to such infrastructure projects. It is also important to emphasize the need to seek mechanisms to engage the client throughout the project, as the active participation of all stakeholders is fundamental to ensuring the successful completion of the implementation journey.

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