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LOGISTICS PLANNING WITHIN THE LAST PLANNER SYSTEM FOR HIGHWAY CONSTRUCTION PROJECTS

Bruno G. Antonini[1], Fernanda M. Pimentel[2], Marcus C. T. Fireman[3], Bernardo M. B. S. Etges[4], Frederico R. Campos[5], João de Lima Junior[6], and Bárbara K. Kronbauer[7]

ABSTRACT

This study presents a new Logistics Planning methodology implemented in a highway construction project from May to December 2022. The objective was to analyze the feasibility of using a Logistics Planning method with the help of a Visual Board, in conjunction with the Last Planner System. The research method utilized was the Design Science Research. A 6-step method was developed to enhance the Lookahead Planning routine. After the implementation of the methodology, a decrease in the total and equipment-related impact hours in the productivity fronts was observed, as well as an improvement in the PPC indicator and labour productivity in each service front. It was concluded that the use of Visual Management, combined with Logistics Planning, stimulates the engagement of the operation's employees around the project schedule, increasing the accuracy of the Master Plan.

KEYWORDS

Lean construction Highways, Last Planner System, Visual Management, Lookahead Planning, Logistics Planning.

INTRODUCTION

Ever-shrinking margins and ever-increasing high-performance goals prompt construction companies to adopt the lean methodology in their construction sites (Tezel et al., 2018). Among all the tools within the Lean Construction methodology, the Last Planner System (LPS) stands out and aims to help in the implementation of Lean concepts in construction sites. Its goal is to create mechanisms to increase schedule reliability (Ballard & Tommelein, 2021). LPS seeks to transform long-term activities (what needs to be done) into medium-term activities (what can be done) by eliminating production restrictions and providing a bank of activities ready to be

[1] M.Sc. Candidate in Civil Eng. at Federal University of Rio Grande do Sul, Lean Consultant at Climb Consulting Group, Porto Alegre, Brazil. bruno@climbgroup.com.br, orcid.org/0000-0003-4437-4664

[2] Lean Consultant at Climb Consulting Group, Graduate in Civil Eng. at Pucrs, Porto Alegre, Brazil. fernanda@climbgroup.com.br, orcid.org/0000-0003-0230-4326

[3] PhD Candidate, M.Sc. Eng., Founding-Partner at Climb Consulting Group, Federal University of Rio Grande do Sul, Porto Alegre, Brazil, marcus@climbgroup.com.br , orcid.org/0000-0001-5843-4715

[4] PhD Candidate, M.Sc. Eng., Founding-Partner at Climb Consulting Group, Federal University of Rio Grande do Sul, Porto Alegre, Brazil, bernardo@climbgroup.com.br , orcid.org/0000-0002-3037- 5597

[5] Director Eng. at Neovia Engenharia, Curitiba, Paraná, Brazil frederico.campos@neoviaengenharia.com.br , orcid.org/0000-0002-5745-7461

[6] Planning Manager at Neovia Engenharia, Curitiba, Paraná, Brazil joao.junior@neoviaengenharia.com.br , orcid.org/0000-0001-5289-0963

[7] Planning Eng. at Neovia Engenharia, Curitiba, Paraná, Brazil barbara.kronbauer@neoviaengenharia.com.br , orcid.org/0000-0003-1370-7331

executed in weekly work plans, thereby generating confidence in the outlined action plan (Ballard, 2000).

In the building construction sector, a wide range of papers aimed at the adoption of LPS can be identified. The same, however, does not occur in the context of Highway construction, as the study of the planning and control system applicability is still in early stages.

Given the above, the objective of this paper is to analyze the feasibility of using a logistics planning method with the aid of a Visual Board, aligned with LPS. The hypothesis that this study sets out to test concerns understanding that the possibility of using Visual Management, combined with logistics planning, would stimulate the engagement of field teams in the lookahead planning, thus increasing the ability to identify constraints and the resource planning. The methods used in a specific case study and the results found are explained below.

LITERATURE REVIEW

In order to better understand the application of the Logistics Planning within the Last Planner System in road construction projects, the state of the art was sought in the International Group for Lean Construction (IGLC) database. On January 3rd, 2022, the keyword "Highways" search resulted in 17 articles. The vast majority of the scientific articles published on the page refer to the development of a Lean Construction implementation project aimed at English highways, called Highways England.[8]

Highways England is a government initiative that aims to improve the overall performance of the supply chain and meet the performance goals and cost reduction targets established by the government of the United Kingdom (HE - Highways England, 2018). The Lean implementation pilot project was developed throughout 2006, culminating in the paper published by Ansell et al., in 2007. The authors analyzed production constraints, measured the number of weekly planned and completed activities, and analyzed the root causes of non-fulfillment with the scheduled tasks through routines and tools based on LPS. Furthermore, they noticed that only 3.6% of the short-term planned activities coincided with the activities set out in the long-term planning, demonstrating little assertiveness of the Master Plan.

Subsequent studies aimed at addressing the reasons for non-compliance and low accuracy of the long-term schedule, as inferred from Fullalove (2013), and the improvements perceived from a more collaborative planning, such as the Last Planner System (Drysdale, 2013). From the identification of these early works on the low engagement of collaborators around the implementation of Lean, subsequent projects aimed to bring new elements that could help with this problem, such as Visual Project Management (Tezel et al., 2016) and the implementation of continuous improvement cells in the highway sector (Tezel et al., 2018a).

Although the aforementioned studies address tools and routines based on Lean Construction, such as LPS, Continuous Improvement, and Collaborative Planning, several studies have found that there is a need for more visual management on the work fronts to increase engagement with field teams. Thus, it is necessary to conduct a preliminary study of the specific needs of each project to avoid the risk of implementing these tools without a clear purpose (Tezel et al., 2018b).

According to Dahlberg and Drevland (2021), the delay in the delivery of materials, equipment, and tools is the main cause of production delays. Dawood et al. (2010), analyzing earthworks operations, share a similar view, pointing out that poor resource planning (materials, equipment, and tools) and low productivity are among the main factors for increased costs and

[8] Of the 17 articles found, 13 were published by authors from the United Kingdom, 9 of which were the result of the Highways England project. The other articles found will not be extensively analyzed here, since they do not relate directly to this research topic.

schedule overruns. Thus, the logistics and dimensioning of resources within the construction site must be planned in order to assist in the flow of balanced production.

Visual information can be an excellent strategy to assist in resource planning and logistic planning, alleviating a gap in the Last Planner System (LPS) and facilitating the visualization of constraints, leading to higher engagement from teams in collaborative meetings. In recent years, there has been an increase in the number of Visual Management (VM) studies in civil construction. However, the visualization of these effects is still done in a conceptual way. Within the context of highways, the study of using Visual Boards is still incipient, with few empirical studies (Tezel et al., 2016b). From the best of the authors' knowledge, the connection between logistics planning and VM is barely explored in the literature.

It is noted that, in the context of highways, visual information is generally limited to health and safety indicators. Nonetheless, it is clear that field teams want to view information related to schedule, quality and planning processes. Tezel et al. (2016a) showed that implementing Visual Boards on highway construction sites helped in mapping and preventing problems, brought greater visibility to planning and improved the coordination and harmonization of work teams.

METHOD

The methodology adopted in this study was Design Science Research (DSR), a method in which the strategy helps in the search for solutions in the field of innovation and continuous improvement by using the research strategy (Carneiro et al., 2019). This research model seeks to develop valid artifacts and reliable knowledge for problem solving (Van Aken, 2004), reiterating that its use must be developed based on the usefulness it will have for the organization and literature, by developing and applying theoretical knowledge (Monteiro, 2015; Järvinen, 2007; Lukka, 2003). The artifact developed was the Collaborative Method of Logistics Planning for sizing the quantity of equipment needed over a period of 6 weeks, linked to a Visual Framework, for highway construction projects.

The method was applied in a pilot study of a highway construction project executed by Company A. Company A operates in the heavy construction sector, offering infrastructure solutions, and has over 1200 employees in its workforce. Company A did not have a specific structured planning method, at the long-term level there was a Gantt-based planning software due to the need established in the contract with the highway concessionaire, the lookahead planning didn´t exist and at the short-term level there was formal planning but without collaboration between team leaders. However, the isolated tools was not sufficient to meet the complexity presented in this project and did not allow the visualization of possible conflicts between different services in the same locations.

The company was starting a Lean transformation process, and this project was chosen as a pilot due to its size and complexity, as the project was already partially executed when Company A entered the project. The construction project, still under construction, is located in Brazil, in the state of Santa Catarina, and has 37 km of extension. The authors of this work were part of the Lean implementation nucleus, consisting of external consultants and collaborators from Company A. The implementation of Lean Construction within the pilot study started in May 2022 with the application of the Last Planner System (LPS).

The steps followed by the research were: (i) identification of the problem after the implementation of the LPS; (ii) mapping Company A's internal systems for adjusting resources; (iii) development and application of the method; (iv) review of the method based on data analysis; (v) assessment of the methodology developed through employee survey and result analysis. The survey was focused on understanding the evaluation of the employees regarding ease of use and usefulness.

The Logistics Planning method was developed iteratively, taking inspiration from the playful approach of some logistic simulation software such as AnyLogic. The parameters and resources sizing calculation were based on Mattos (2019). Table 1 summarizes the main sources of observation used to refine the artifact and collect data for analysis.

Table 1: Main sources of evidence.

Case Study	Highway Construction Project
Duration	6 months
Number of meetings	12 meetings (estimated total of 24 hours)
Participant observation in planning meeting	Bi-weekly Logistics Planning meetings and daily huddles
Role of the observer	Initially led meetings during routine implementation. Then transitioned to a spectator providing insights and improvement suggestions for meeting management
Direct observations	Informal conversations and observations during the daily huddles
Document Analysis	Schedule, daily huddles, weekly plans, and the materials factory, internal processes for hiring and mobilizing equipment and purchase of material
Employee Survey	10 Collaborators (field managers, engineers, project director, and contract manager)

The project involves a two-lane highway with flexible pavement and five layers. Excavation is done first, followed by rock fill and subgrade layers (25 cm each) locked with fine material. Sub-base layer (25 cm) follows with Macadam and fine material. Then the Single-Sized Gravel (SSG) base layer (15 cm) and the hot mix asphalt (HMA) pavement layer (3 parts) are added. Understanding each layer is important for specific equipment and cycle times, affecting logistics planning.

METHODOLOGY DEVELOPMENT AND INITIAL RESULTS

PROJECT DIAGNOSTIC ASSESSMENT

The project started with the introduction of the LPS and its management tools, as requested by Company A. A Master Plan was developed using the Time-Location planning technique and daily Check in-out meetings were established. Using these daily routines, relevant data and key performance indicators (KPIs) were collected to detect issues in the field. The analysis revealed that equipment-related interferences from field teams accounted for 43% of all interferences, with much of it stemming from inadequate supply to the service fronts. Further on-site inspections were carried out to determine the true nature of the problems reported by the field teams.

A notable aspect of the project undertaken with Company A is that two other companies had previously carried out separate sections of the highway. This added complexity to the planning process, as the activities were not performed in a linear manner and internal logistics were hampered by the extended travel required to cover the scattered activities throughout the construction site.

During the workflow analysis in the service fronts, a clear connection between value aggregation and equipment resources was identified. Figure 1 showcases one of these observations carried out in the Macadam work front in August 2022. During a 1 hour and 30 minute observation period, it was observed that the tractor remained idle for 52 minutes, accounting for 58% of the total time. This idle time is represented in red in Figure 1, while the green section represents the time when the equipment was active. This revealed that the equipment quickly returned to inactivity after a period of truck unloading. As a result, the number of dump trucks was adjusted to increase the delivery frequency of materials and meet the daily production target set in the Master Plan. The findings align with those in the literature. Haronian and Sacks (2020) carried out three studies to calculate value aggregation in earthwork fronts and found that the percentage ranged from 36% to 58% of the total work time.

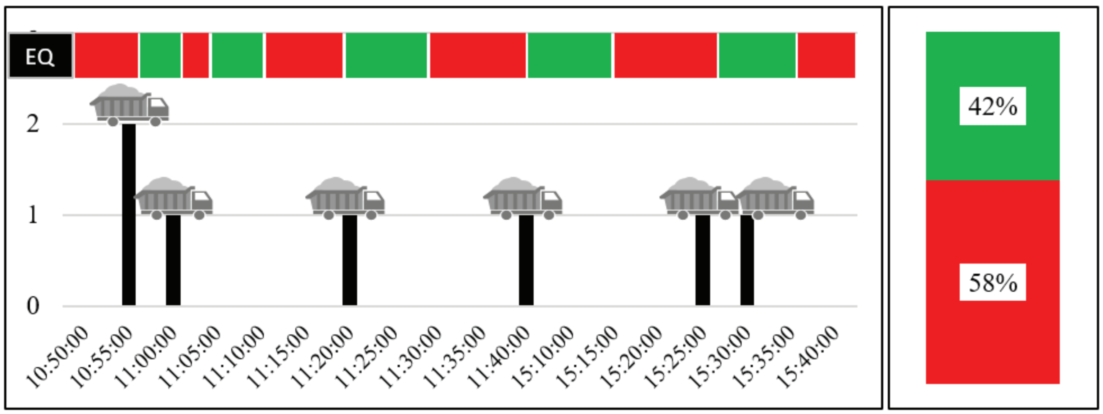

Figure 1: Field observation based on chronoanalysis carried out on the macadam front in August 2022.

Additionally, initial interviews were conducted and it was identified that field staff had difficulty visualizing medium-term constrains when presented with work plans outlined in the standard LPS models. This highlights the shortage of the medium-term model, as field employees struggled to map and size equipment for the sections that needed to be produced. Given this information and the imbalance of field resources, it became necessary to develop a routine that could dimension the necessary resources in advance for the project's execution, while also having the action plan for the coming weeks represented in visual charts alongside the project map.

Given the demand for the improvement of LPS routines for field teams, a complement to the classic framework by Ballard (1994) was proposed, as shown in Figure 2, combining the Look Ahead Planning routine with Logistics Planning. To this end, a method was created for sizing equipment needs according to what was planned in the Master Planning, using the expected productivity and cycle times of each equipment, in order to better visualize equipment-related restrictions.

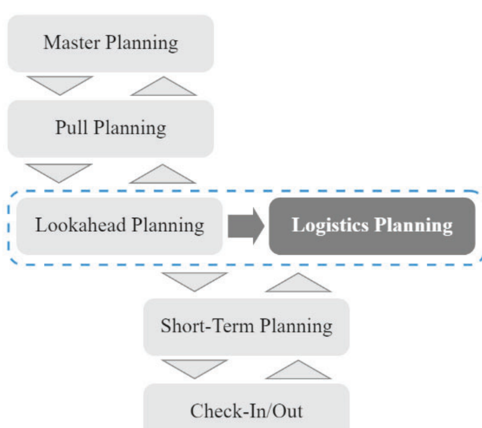

Figure 2: Proposed Logistics Planning and LPS Framework, adapted from Ballard (1994).

Logistics Planning is positioned alongside the Lookahead Planning step due to their similarities. Lookahead Planning seeks to visualize a production horizon, based on updates and adjustments to the Master Planning, and through the mapping and removal of constraints, allocate only activities that are cleared for execution in the upcoming weeks (Ballard, 1997).

To determine the study horizon in this routine, the average time for driver and equipment mobilization was checked with the human resources and equipment departments within the company. During the study, it was found that the average time between the request and the entry of employees with the equipment took, on average, 4 weeks. Hence, the method presented here takes place within a 2-week interval, with a planning horizon of 6 weeks, in order to have a reasonable hiring time when an eventual need is identified.

METHODOLOGY DEVELOPMENT

After conducting this diagnosis with the work teams, the need to hold a Logistics Planning meeting on the construction site to calculate the quantity of equipment was identified. A 6-step model was then developed for conducting Logistics Planning in highway construction projects.

Step 1: Scope Analysis

In this first step, it is necessary to have the Master Plan developed, with a clear action plan, as well as to have the productivity of the equipment of each service fronts, as shown in Figure 3a. In the Company A scenario, six main services are identified: Excavation, Rock Fill (or Land Fill), FEL (Final Earthwork Layer), Macadam, SSG (Single-Sized Gravel), and HMA (Hot Mix Asphalt). For each of them, there are productivity rates planned to meet the long-term planning, along with the equipment's own productivity. With this information, it is possible to analyze the production volumes for each of the lots and the deadlines for completing each activity in the location where it should be executed.

Step 2: Sequencing of Fronts

After completion of Step 1, the action plan is reviewed and defined with the field team, as well as the sequencing of the service fronts. This step aims to map out the ideal workflow for executing the work, considering the priority production batches and also the contractual milestones imposed by the client. As shown in Figure 3b, the fronts that will be worked on over the next 6 weeks are placed in the Visual Board. Different colors were used for each service in order to visualize the workflow over the weeks. It is also important to consider the interdependence between activities, so that all can be completed in an adequate manner.

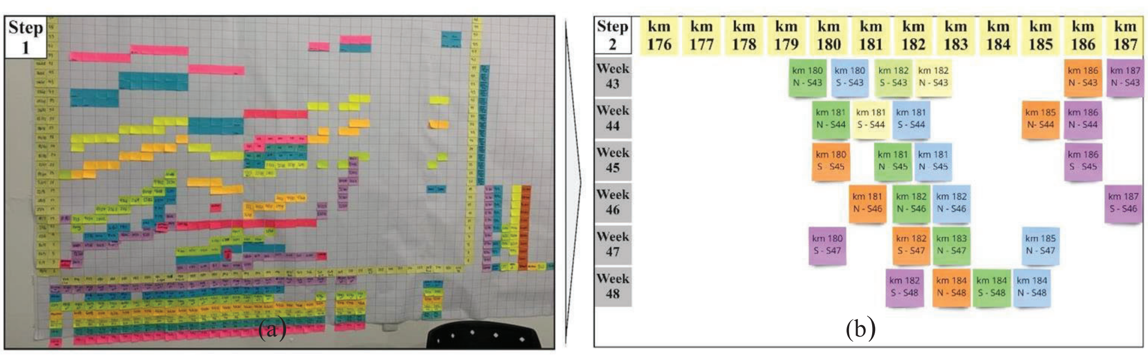

Figure 3: (a) Step 1: Master Plan defined; (b) Step 2: Visual Board with 6-week planned work fronts.

Step 3: Supply Logistics

In this step, the feasibility study and analysis of material extraction sites is carried out in order to attend the construction production and visualize the material supply routes and note the necessary distance for material transportation. The Visual Table indicates where the material pickup (Storage – ST) and deposit locations (Land Fills – LD) are, as shown in Figure 4a.

Step 4: Supply Cycles

With data already analyzed in the field, such as cycle time (Figure 4a), material loading and unloading, as well as the information on location, execution deadline, transportation distance, and heavy machinery productivity, a calculation is made of the number of dump trucks required, as well as the number of trips needed by each truck throughout the day, to meet the established goals. The information on the compliance with the plan is then collected in daily huddles, in order to have an agile response and schedule corrections within the same week.

Step 5: Resource Sizing

With the drawn plan, it is possible to balance the best workflow, respecting large mobilizations and demobilizations of trucks from week to week. Thus, the aim is to arrive at a plan that is more consistent with the reality of the work. The logistics planning is updated every 2 weeks, i.e., there is always a 4-week protection for the planned horizon, which, as mentioned earlier, is sufficient time to mobilize equipment and drivers within the company. With the work fronts and locations of material removal and deposit defined, as well as with the number of dump trucks established, it is possible to design the truck routes on the Visual Board, as shown in Figure 4a, thus starting Step 6.

Step 6: Constraint Analysis

As part of the Lookahead Planning routine, in this phase, employees are encouraged to map out any constraints that may hinder the execution of the proposed plan. With the Logistics Planning Visual Board positioned below the job site map, employees found it easier to map production risks and see attention points that could impact labour productivity in each service front. From the mapping of the restriction, proactive actions can be taken to mitigate or even eliminate it before it becomes an interference and, as a consequence, impacts the productivity of the work front. For each mapped constraint, actions and responsibilities are listed on another Visual Board, to eliminate them and thus release the activity for execution. To protect production, these actions are transferred to a spreadsheet by the Planning team and sent to each of the responsible service front parties. As the actions are completed, they feed the Constraint Removal Index (CRI), as shown in Figure 4b.

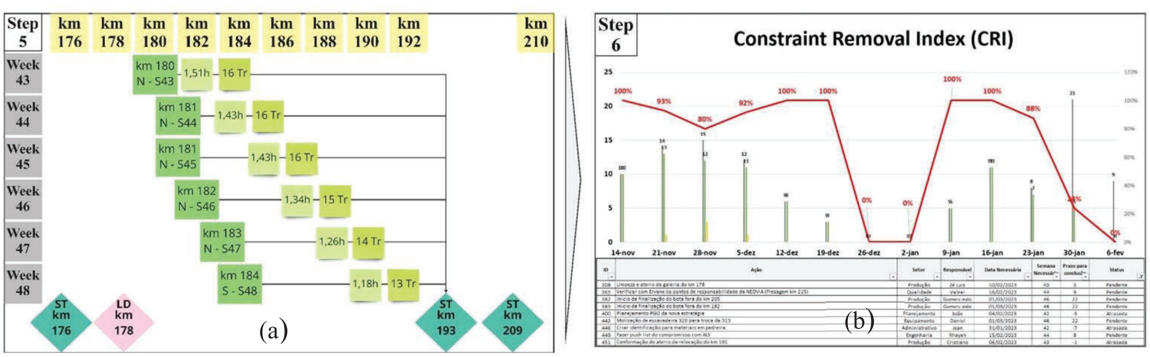

Figure 4: (a) Step 3 to 5: (3) Locations and routes of deposit and withdrawal of material mapped; (4) calculation of the cycle time; (5) Sizing and balancing resources; (b) Step 6: Control of removal of restrictions based on visualizing obstacles to productivity.

As these 6 steps were developed, it was possible to observe a greater level of worker and field team engagement in adhering to the long-term planning, considering the increase in PPC, as shown in Figure 7a, and the productivity in the field, Figure 7b. Furthermore, with the implementation of the Logistics Planning Visual Method, workers were observed to have developed a higher level of responsibility regarding the elimination of the mapped restrictions. Beyond participation in the meetings, workers would take photos of the visual board, presented in Figure 5 in order to meet established goals. This team engagement confirms what Ballard and Tommelein (2021) bring in their LPS benchmarking work. The Lookahead meetings should be collaborative, involve all the responsible parties from the service fronts, including the decision makers and on-site workers who can provide the necessary information for the meeting to proceed. Only in this way is it possible to create a functional activity sequencing plan with flows and transformations.

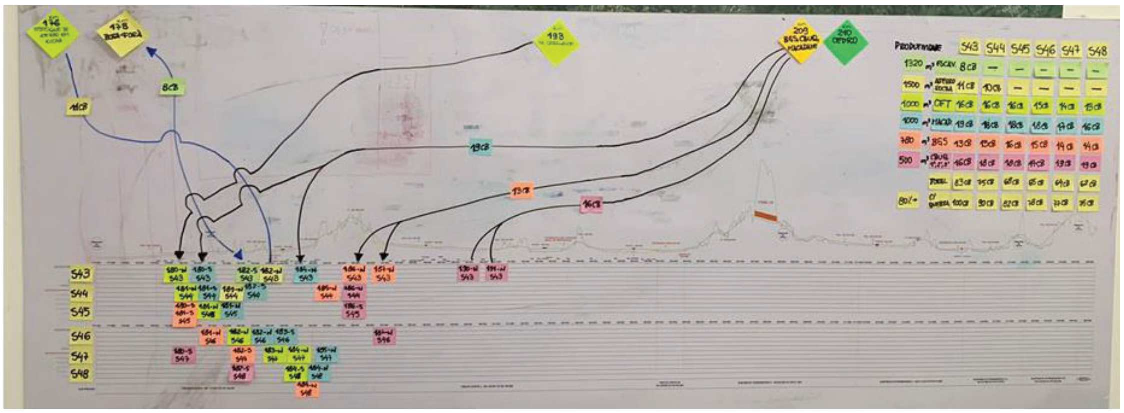

Figure 5: Routine of Logistics Planning and Visual Table of sizing trucks and routes

INITIAL RESULTS

After the implementation of the 6-step Logistics Planning method, an improvement could be noted in the primary indicators consulted, when compared to the months of June, before the beginning of the Logistics Planning meetings, and November, after the beginning of the Logistics Planning meetings. The total hours of impact correspond to the hours that services remained stopped, whether due to lack of material, equipment, project, or other factors. Hours related to equipment refer specifically to those hours that services remained stopped due to a lack of equipment. Figure 6 shows that the total number of hours of impact in productivity during the Check in-out meetings decreased from 881 hours in June to 278 hours in November, which represents a 68% decrease in total hours. Similarly, a decrease in the hours of impact related to equipment was observed, from 43% (374 h/881h) in June to 29% (81h/278h) in November.

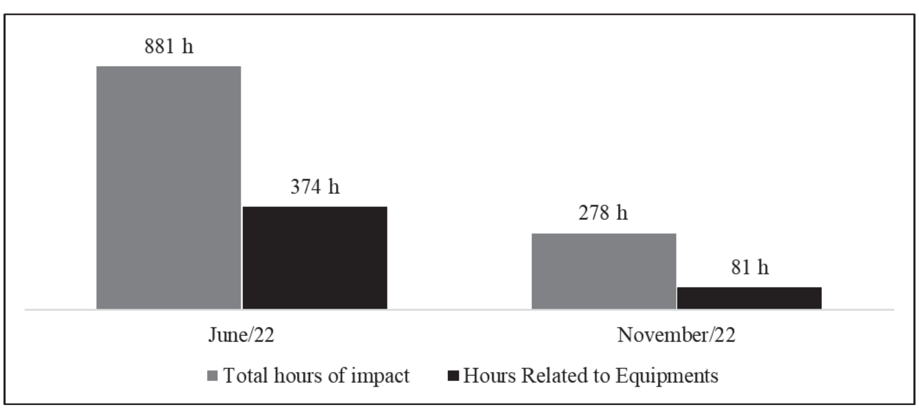

Figure 6: Hours of impact in productivity, total and equipment-related.

There was also an improvement in the PPC indicators, as shown in Figure 7a. The PPC indicator showed continuous growth since June, from 20% to 52% at the end of the collection in November. This percentage is due, among other factors, to the complexity of the section, as mentioned during the implementation of the LPS, and due to the recurrent rains in the region during that period consisting of rain on 41% of the days.

The data found is corroborated by Tezel et al. (2016a), who, in two road projects, identified an increase in PPC after the implementation of visual management on the construction site. In the first, PPC increased from 60% to 85%, while the second had an average PPC of 76%. Drysdale (2013) also achieved similar improvement values, rising from 59% to 85% in Percentage of Plans Concluded.

Figure 7b shows an improvement in the indicators of labour productivity. This indicator was used to identify whether the Logistics Method helped the team, resulting in an increase in production from the Sub-grade, Sub-base, and Pavement Base fronts. Thus, the calculation used to verify this increase was the ratio between the monthly volume produced and the number of hours worked. For the Sub-grade front, there was a 64% increase in productivity between June and November, while the Sub-base and Base front saw a 7-fold increase in productivity.

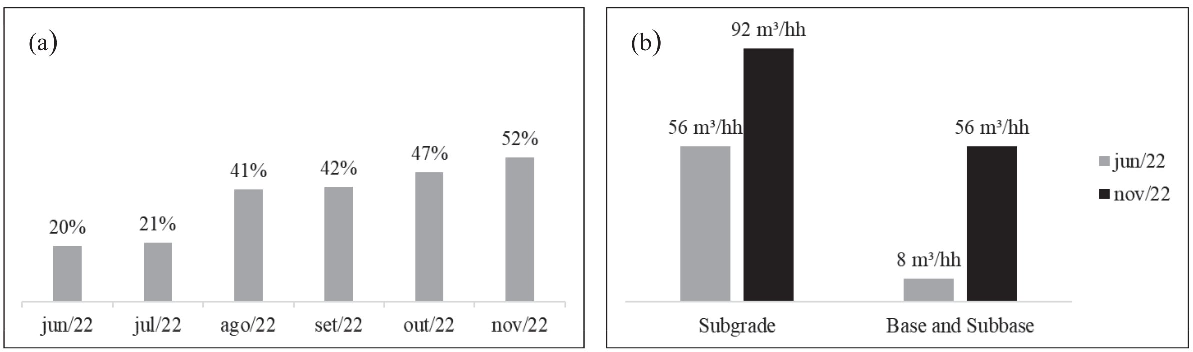

Figure 7: (a) Percentage of Plans Concluded (PPC) during the development of the Project: (b) Increase in Productivity of the service fronts before and after starting the Logistics Planning meetings.

In order to evaluate the usefulness and effectiveness of the proposed method in mapping constraints, and to separate the normal learning effect of teams, a survey with ten collaborators were done, including field managers, engineers, project director, and contract manager. Their responses, tabulated in Table 2, indicate a widespread approval of the method. While three out of the ten interviewees reported challenges in applying the method, all of them expressed the inclination to recommend it for future projects.

Table 2: Main sources of evidence.

N	Questions about the Logistics planning method	Strongly Agree	Agree	Disagree	Strongly Disagree
1.	Do you use the method for highway construction in your company?	9	1	-	-
2.	Is the method used by the company efficient?	8	2	-	-
3.	The method used by the company has improved the mapping and analysis of constraints?	9	1	-	-
4.	The method used by the company has improved the perception of resource sizing?	9	1	-	-

5.	The method used by the company has improved the visualization of where to deploy resources?	8	2	-	-
6.	Do you consider the logistic planning tool used by the company easy to apply?	7	3	-	-
7.	Considering usefulness and ease of use, do you approve of the method used by the company?	9	1	-	-
8.	Would you recommend the use of this method for future projects?	10	-	-	-

CONCLUSIONS

This study presents a new Logistics Planning methodology implemented in a Highway project between May and December 2022. The objective was to analyze the feasibility of using a logistic planning method with the aid of a Visual Board, combined with the Last Planner System.

The methodology employed is well-suited for LPS and is complementary to Lookahead Planning, given their similarities: (i) definition of the production batch sequencing; (ii) mapping and removal of production constraints; and (iii) the need to hold collaborative meetings. Six steps were developed to increase the lookahead planning, consisting of: 1. Scope Analysis; 2. Sequencing of Fronts; 3. Supply Logistics; 4. Supply Cycle; 5. Resource Sizing and 6. Constraint Analysis.

After the implementation of the methodology, a decrease in the number of impact hours (total and equipment-related), was observed. Additionally, there was an improvement in the PPC and productivity indicators of the service fronts. The results are corroborated by the literature (Tezel et al. 2016a; Drysdale 2013). Furthermore, the more visual and collaborative format of the meetings helped in the engagement of the field teams, who took photos of the developed visual board for on-site use.

Therefore, it can be concluded that the possibility of using Visual Management, combined with logistics planning, stimulates the engagement of the operation's employees around the construction schedule, increasing the accuracy of the Master Plan, confirming the hypothesis proposed.

An interview was conducted to perform a cross-analysis between the users' perception regarding the usefulness and effectiveness of the method. It was possible to perceive that the method was widely approved of, although some interviewees found it challenging to implement. Nonetheless, all interviewees expressed their willingness to recommend the method for future projects.

Despite finding improvements with qualitative and quantitative data, the implementation of Lean in highway construction projects must take into consideration the need to actively involve field collaborators in routines that facilitate the visualization of restrictions, in a simple manner that is easily understood. Companies need to go beyond simple implementation and actually incorporate supply chain and equipment routines into their projects, making strategic decisions aimed at increasing efficiency in the sector.

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