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ROADMAP FOR IMPLEMENTING STANDARDIZED WORK IN CONSTRUCTION PROCESS WITH TAKT TIME PLANNING

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ABSTRACT

Lack of predictability, high workforce turnover, and making-do are some of the factors that contribute to process variability in construction. Variability can disrupt workflow, negatively impacting the performance of production systems in terms of cost, duration, and project quality. Standardized Work (SW) is an approach from the Lean Production Philosophy that enhances process stability by establishing procedures that standardize each worker's tasks. However, despite its widespread application in the manufacturing industry, the full potential of this approach remains underutilized in construction. This paper presents the results of implementing SW in the concrete structure process of a residential project undertaken by a Chilean company. The study adapts the key elements of SW to the construction context and engages workers in defining a standard routine. Action research is the methodological approach adopted in this study. The results show that SW, along with interventions supporting continuous improvement, reduces operational variability, enhances workspace organization, and increases workers' self-management in meeting their goals. This approach improves the operational efficiency of construction projects and contributes to a broader understanding of effective strategies for managing process variability in construction.

KEYWORDS

Standardized Work, Takt time, Takt Time Planning, Continuous Improvement, Variability.

INTRODUCTION

Variability is an inherent characteristic of construction projects, requiring effective management to ensure success. In this context, is a fundamental management strategy for minimizing variability in production processes (Fazinga, W. R., 2012). In the Lean Production Philosophy, standardization focuses on the operations performed by workers (Martin & Bell, 2017) and is known as Standardized Work (SW) (LIB, 2003).

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Spear & Bowen (1999) emphasize that the specification of SW constitutes the hypothesis of best practice, which is constantly tested with the participation of both leaders and workers. The procedures developed based on SW specifications lead to standardization and establish a reference for continuous improvement (Liker, 2004). However, despite the critical role of SW in continuous improvement, it remains one of the most underutilized aspects of the Lean Production Philosophy in many companies (Ohno, 1997).

Ohno (1997) identifies three essential elements for defining SW: takt time, standard sequence of operations, and standard inventory. According to Alvarez & Antunes (2001), takt time is determined by customer demand and available production time; it represents the production pace required to meet demand. The standard sequence of operations refers to the activities performed by a worker or team throughout the cycle time (Monden, 2011). Standard inventory refers to the minimum quantity of items necessary to carry out a process efficiently, allowing workers to perform their tasks effectively (Ohno, 1997).

As highlighted by Fazinga (2012), in production environments different from manufacturing, even though the objectives of SW implementation align with Lean Production, its elements may require adaptation due to industry-specific characteristics. In this regard, Bonesi-De Luca (2024) proposed the following SW components for construction processes: (a) Takt Time: defined as the ratio between available production time and the number of locations to be produced. It represents the resulting pace from process synchronization, aligned with the overall construction plan; (b) Cycle time per worker or team: this should be defined as the maximum number of days allocated for each worker to execute a set of operations in each location, slightly lower than the takt time; (c) Standard Kit: this consists of requirements that, if not met, may limit SW performance. Standard kit components may include: design documents, labor, materials, tools and equipment, space, safety, worker training, and key personnel involved in the process execution; (d) Standard execution trajectory: this refers to assigning each team to different production lots and indicating the order in which they should complete them to start and finish an activity; (e) Standard sequence of operations: this defines the order in which a worker should execute a set of operations within the production lot for a given process.

Takt time is closely associated with Takt Time Planning (TTP), a location-based planning and control approach aimed at synchronizing processes through collaborative planning meetings (Binninger, Dlouhy & Hagsheno, 2017). The goal of TTP is to identify repetitive processes and balance them to enable a stable, uniform flow, with takt time playing a key role in process synchronization (Binninger, Dlouhy & Hagsheno, 2017). According to Vargas et al. (2023), integrating SW with TTP allows for the synchronization and balancing of activity resources, increasing process stability. These authors argue that this integration serves as a mechanism for managing variability and increasing process standardization.

In the context of the construction industry, the application of SW contributes to the reduction of non-value-adding time, the improvement of working conditions, increased productivity, the establishment of more efficient workflows, enhanced reliability of the production system, and the strengthening of worker autonomy (Fernandes et al., 2015; De Bortoli Saggin et al., 2017; Vargas et al., 2023). On the other hand, in complex systems, such as construction projects, the number of interdependencies between activities is often considerable (Koskela, 2000; Bertelsen, 2003). Consequently, certain preconditions for the commencement of work may remain unmet, which can hinder the effective implementation of SW (Fireman et al., 2018).

The literature on SW in construction (De Bortoli Saggin et al., 2017; Fernandes et al., 2015; Fireman et al., 2018) remains limited, with many studies primarily focusing on data collection methodologies. These studies often fail to offer clear guidelines for adapting SW elements to the construction context or for effectively implementing SW on construction sites. Moreover, existing research on SW in construction tends to overlook the involvement of workers in defining standardized routines. Therefore, the primary objective of this paper is to present the results of SW implementation in a Chilean company, emphasizing the involvement of team leaders and workers while considering SW elements adapted to the construction context. As a secondary objective, this study aims to propose a roadmap for implementing SW in construction processes with TTP. This approach can enhance the operational efficiency of construction projects and offer effective strategies for managing process variability within the construction industry.

RESEARCH METHOD

The research method adopted in this investigation was Action Research, based on a Case Study. Action Research is an approach that allows for the active participation of the researcher in the observed phenomenon (Thiollent, 2005). Thiollent (2005) defines Action Research as a specific type of empirical research designed and conducted through action, in which researchers and some participants of the situation or problem are cooperatively involved. According to Dick (1993), Action Research has two objectives: action, to drive change in organizations, and research, to enhance understanding of the studied topic.

A Lean Implementation Program was conducted with support from a Brazilian consulting firm, where researchers also acted as consultants and facilitators. They worked closely with the company's stakeholders, implemented changes based on findings, and engaged in continuous reflection to refine the methodology and address challenges. The results were shared with relevant employees.

CASE STUDY

The present study was conducted at a construction company specializing in vertical and residential buildings within the Chilean real estate market. The company was selected for this study for the following reasons: (a) it applies various management concepts and methods based on Lean Production; (b) it has a formalized Production Planning and Control (PPC) system that incorporates several elements of the Last Planner System®; (c) it uses TTP as an approach to Long- and Medium-Term Planning in its projects; (d) it was interested in conducting detailed studies on the standardization of critical operation cycles to improve project outcomes.

The project under study, located in La Serena, Chile, is a residential condominium with 120 apartments across eight seven-story towers (six residential floors and one with storage units). Construction is divided into four phases of four towers each. This study focuses on the concrete structure of towers 3 and 4 from phase 3 and tower 5 from phase 4, composed of reinforced concrete walls, beams, and slabs. SW implementation began in April 2024, with monitoring until November 2024. Figures 1 and 2 show the towers from phases 3 and 4 and the line-of-balance tool used for planning and control.

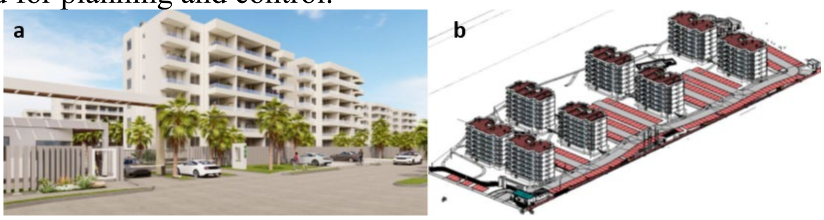

Figure 1: (a) Project under study and (b) 3D representation of the project under study

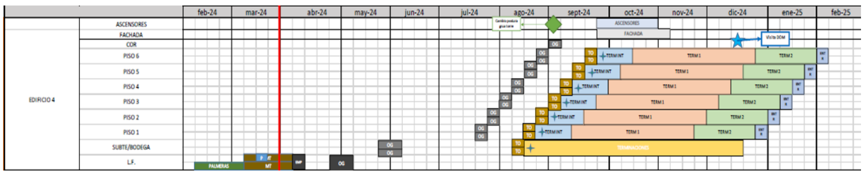

Figure 2: Line-of-balance

ROADMAP FOR IMPLEMENTING STANDARDIZED WORK

The implementation of SW was led by a team consisting of external consultants, the chief site engineer, the planning and control coordinator and analysts, the quality supervisor, and the safety supervisor. Other field engineers, the concrete structure foreman, and team leaders for formwork, carpentry, and rebar also actively participated in the weekly SW implementation meetings. In addition, they assisted in real-time data collection and conducted analyses of the data. The following sections describe each key stage of the SW implementation process:

1. **Selection of the Critical Process:** the first stage involves selecting a critical process for implementing SW. An analysis was conducted on the project designs, the overall construction schedule, the budget, and interviews with the project management team. The criteria for selecting the critical process were as follows: (a) the potential to limit the delivery rate of successor activities, impacting the project's final completion deadline; (b) a construction phase characterized by a significant increase in the number of activities and equipment, making control more complex; (c) a construction phase with a high degree of interdependence between activities.
2. **Development the Critical Process Design:** through on-site observations and discussions with the project management and production teams, the best approach to execute the process and meet the balance line pace was defined. This involved reviewing the sequencing of concrete structure process activities, analysing operations to define the necessary number of workers, ensuring the continuous and synchronized work of teams, and validating technical allowances and buffers.
3. **Current status of value-added and non-value-added activities**: in order to monitor non-value-added activities on construction sites, the Work Sampling Method (WSM) was applied. As described by Jenkins & Orth (2003), WSM involves making a series of instantaneous observations, like snapshots, of ongoing work over a period of time to measure worker productivity. This method, therefore, allows for identifying moments of low productivity, which in turn can generate sufficient information to carry out the necessary corrective actions (Thomas & Napolitan, 1999). The research lasted 20 hours, collecting data on the operational times of rebar workers, carpenters, and electricians, using the Process Study Sheet (PSS)[6] worksheet to record the information. Activities were classified into value-adding (transformation) and non-value-adding (waiting, transportation, inspection, and rework), with graphs generated to illustrate this distribution. Although the measurements had limitations, they served as a preliminary survey. Additional observations were made regarding workspace organization and the sequence of operations, and the data were presented to the management and production teams to propose improvements in the operational cycle and process refinement.
4. **Development of Visual Management Tools to Support Standardized Work**: visual tools were developed to explicitly outline all elements of SW, which were established throughout the previous stages. The objective was to support SW and ensure clear and effective communication among construction teams. These visual tools were used to formalize the implementation of SW, train the workforce, and monitor its application.
5. **Identification of the Standard Kit:** the components of the standard kit were identified for each set of operations. The objective was to ensure that all necessary components were available before and during process execution. To ensure that all stakeholders were aware of the required components for each activity, a presentation was conducted with the key personnel involved in the execution process.

[6] The Process Study Sheet is a spreadsheet that helps collect process times, through timing and identification of each work element (LIB, 2003).

6. **Monitoring Standardized Work Using Control Tools:** Weekly on-site data was collected on execution times, team movement, work sequences, and standard kit availability. Adherence charts for planning and cycle time were created for each team, allowing comparisons between actual production and planned targets. These charts were discussed in weekly meetings with the project management team and consultants. The analysis focused on cycle time variability, delays, deviations from the planned sequence, incomplete processes, excessive work-in-progress, and uncompleted production batches.
7. **Future status of value-added and non-value-added activities**: new on-site observations were conducted using the WSM, with 15 hours of data collection on the operation times of rebar workers, carpenters, and electricians. The data from the future state mapping was presented to the project management and production teams to: (a) assess if the proposed alternatives reduced non-value-adding time, (b) identify potential improvements in the operation cycle, and (c) establish new actions to further reduce non-value-adding time.
8. **Standardized Work Evaluation**: the consultants provided a document to assess the implementation process of SW, which was used to evaluate the implementation of SW in the case study. The purpose of this document was to assess the overall performance of the process based on evaluation criteria for each element of SW.

RESULTS

The following presents the results for each stage of SW implementation:

1. The **concrete structure process** was selected for the implementation of SW**.** This process was selected based on the following criteria: (a) it was a process whose individual capacity constrained the overall production capacity of the system; (b) the company aimed to standardize operations in this process to ensure daily slab concreting and improve work organization.
2. **Development of the Critical Process Design**: the optimal trajectory (Figure 3a) and execution sequence (Figure 3b) were defined. Based on these definitions, the critical process design was developed (Figure 3c), incorporating key elements of SW: (a) a takt time of one floor every seven days; (b) cycle time for each team (represented by different colors); (c) standard execution trajectory; and (d) standard sequence of operations.

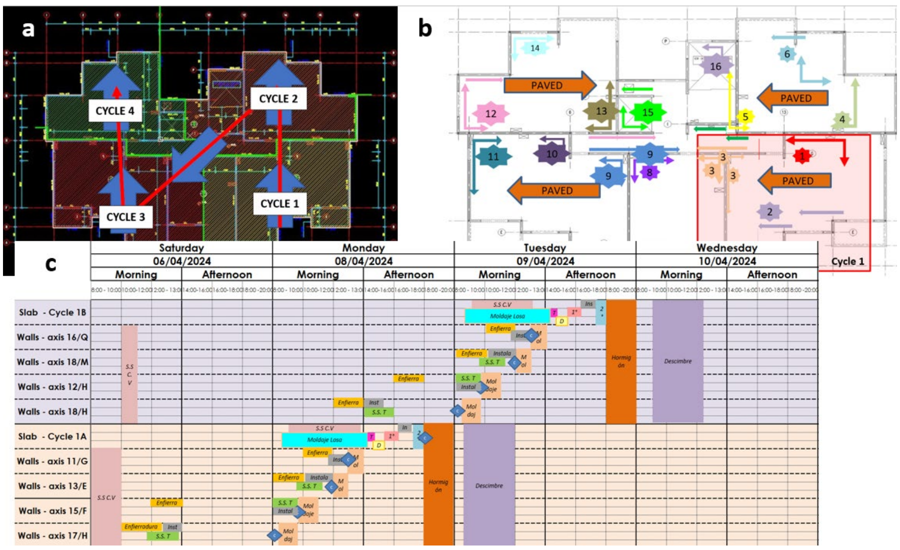

Figure 3: (a) Standard Execution Trajectory, (b) Standard Sequence of operations and (c) Critical Process Design

3. **Current status of value-added and non-value-added activities**: Figure 4 shows the time distribution for a rebar worker, highlighting non-value-adding activities. For the rebar team, time was spent on material retrieval and waiting for length verification before placing bars. The carpenters' team spent most of their non-value-added time on material movement, while the electricians waited for rebar mesh placement before starting their work. Based on these findings, improvements were proposed for the rebar workers, including better access to the slab, improved control of mesh dimension checks to avoid unnecessary cuts, and better organization of steel bars by diameter.

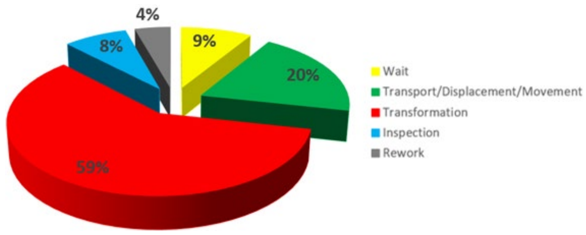

Figure 4: Current State – Distribution of Operations for a Rebar Worker

4. The following **visual management devices** were developed: standard operation sequences, floor location trajectories, partial goals for completing SW, indicator boards, progress graphs, and monitoring of adherence and cycle time. These tools made critical information easily accessible, helping visualize goals, results, and processes, ensuring compliance with standards, identifying deviations quickly, and optimizing decision-making. Their implementation enabled more agile, aligned management, fostering continuous improvement and enhancing transparency and control over project progress. Figure 5 shows examples of these Visual Management boards.

Figure 5: (a) TE Schedule Board, (b) Cycle Time Monitoring, Trajectory and Standard Kit, (c) Kanban for Steel

5. Identifying the **standard kit** was crucial for work continuity and optimizing production flow. A detailed presentation was given to key construction team members, highlighting the kit's importance, organization, and efficient allocation. Implementing the standard kit improved agility and reduced waste, as the team was ready to start without searching for materials, ensuring more efficient execution. This practice reinforced the SW culture, maintaining quality and safety standards. Figure 6 illustrates the standard kit's application.

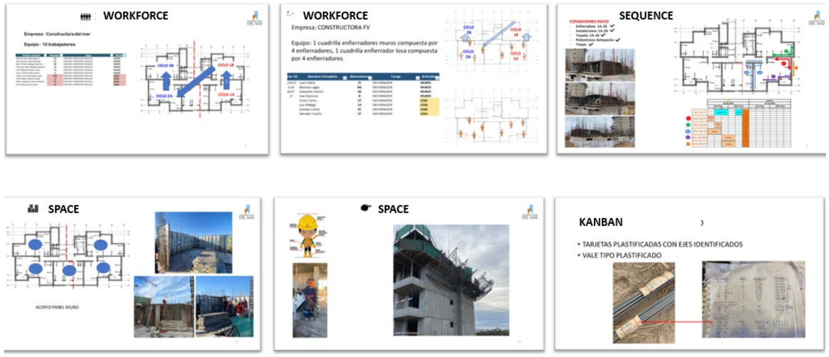

Figure 6: Application of the Standard Kit

6. **Monitoring Standardized Work Using Control Tools**: Figure 7 shows the "Adherence to the SW Planning control tool," with data in 7a reflecting the initial SW implementation phase and 7b showing a more advanced stage. The comparison indicates improved adherence after several SW execution cycles. Figure 8 displays the increasing stability of completed plans for the concrete structure process. These tools helped identify failures early, enabling continuous process adjustments and better project control, ensuring compliance with established standards.

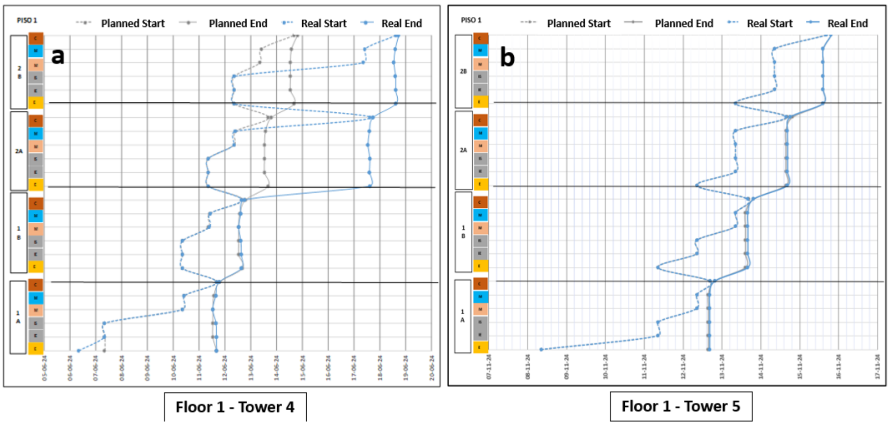

Figure 7: (a) Adherence to the SW Planning on the 1st Floor of Tower 4 and (b) Adherence to the SW Planning on the 1st Floor of Tower 5

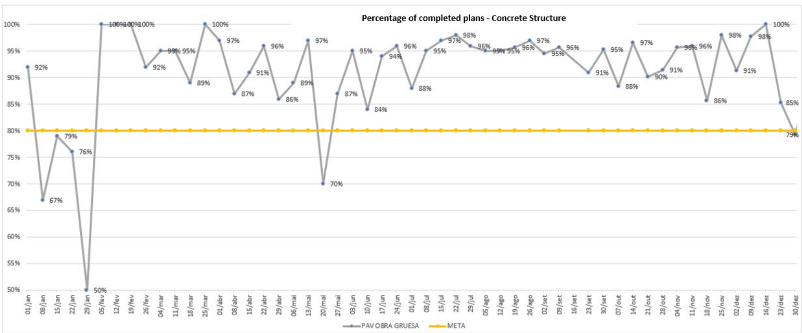

Figure 8: Percentage of Completed Plans (PPC) Concrete Structure

7. **Future status of value-added and non-value-added activities**: Figure 9 shows the time distribution for a rebar worker after implementing SW. The data analysis revealed improvements in site organization to reduce transport and movement. For rebar workers, better material proximity and an efficient Kanban system reduced movement and waiting time. Carpenters benefited from an improved logistical system for formwork, reducing unnecessary movements and optimizing workflow. For electricians, better

coordination with rebar mesh placement eliminated waiting times and ensured timely electrical installations. The future state mapping helped measure these improvements, aiming to increase process efficiency and productivity.

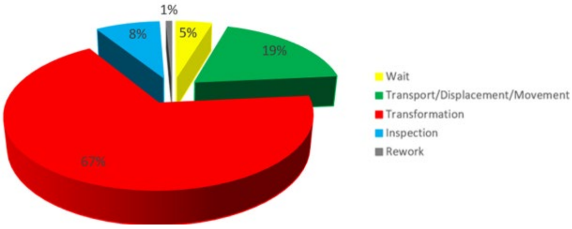

Figure 9: Future State – Distribution of Operations for a Rebar Worker

8. **Standardized work evaluation** in critical processes should use pre-defined criteria to ensure consistency and efficiency. Key components like the availability of the standard kit, takt time adherence, cycle time stability, and operation sequence are vital for monitoring compliance. Visual tools and mapping of current and future states help identify improvements and refine SW. Rigorous control of production cycles, including dates, cycle time, and rhythm, reduces waste and optimizes activities. Categorizing performance as "delayed," "on schedule," or "ahead" allows for continuous adjustments, while a cycle of reflection and corrective actions drives strong performance.

DISCUSSION

The stability and improvement of execution rhythms in critical processes are essential for ensuring efficiency and meet deadlines. The implementation of SW, combined with the analysis of rhythm deviations, provided a clear view of the impact of deepening operations on the progress of the critical concrete structure process. The comparative graphs presented in Figure 10, showing data before and after the implementation of improvements, clearly demonstrate that the adoption of the SW approach and the continuous monitoring of rhythm deviations resulted in greater stability in the critical process. The control and analysis of execution rhythms enabled better forecasting of activity deadlines (Sterzi, M. P. & Bonesi, F., 2024) and provided valuable insights for operational adjustments, enhancing the ability to manage deviations and recover delays, with clear benefits in reducing cycle time variability and improving workflow.

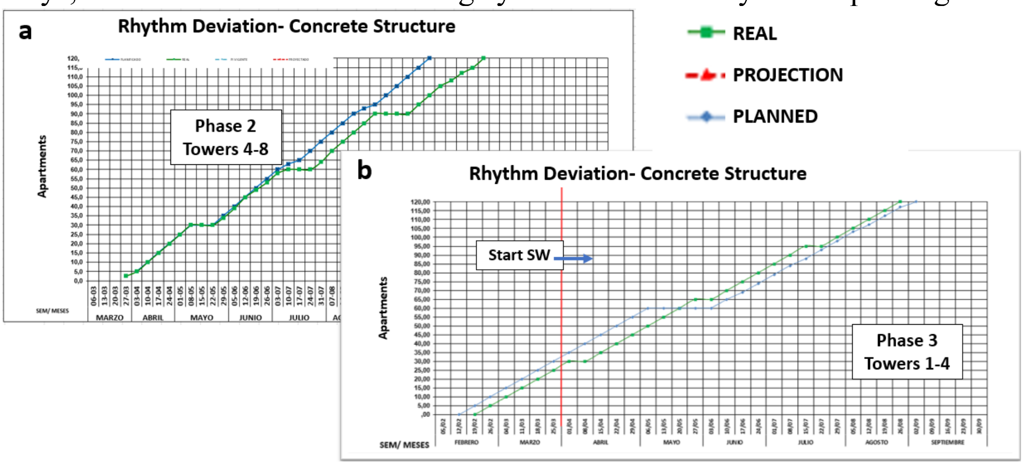

Figure 10: (a) Rhythm Deviation Before the Implementation of SW and (b) Rhythm Deviation After the Implementation of SW

The implementation of SW in the construction process proved crucial in improving both productivity and work quality. By redistributing activities and continuously analyzing of waiting times and movements, it was possible to reduce physical losses and waiting times for materials and equipment. The analysis of worker and team performance allowed for the identification and correction of inefficiencies, boosting the overall performance of the project. Quality control was also strengthened, with a notable reduction in observations in the quality protocols, indicating improved in task execution and a decrease in rework. Figure 11 presents two distinct moments of the project, before and after the implementation of SW. In the images, it is possible to observe a better organization of materials on the slab and the execution of the wall and slab structure of cycle 1 within the execution timeframe.

Figure 11: (a) Before: Tower 01 18-04-2024 and (b) After: Tower 05 29-11-2024

Another significant advancement was the balance in the workload, with a considerable reduction in overtime hours (Figure 12). This not only had a direct impact on operational efficiency but also contributed to enhancing the well-being of the workers. The implementation of strategies such as redistributing activities and optimizing working times improved working conditions, resulting in greater satisfaction among the team and a reduction in labour turnover.

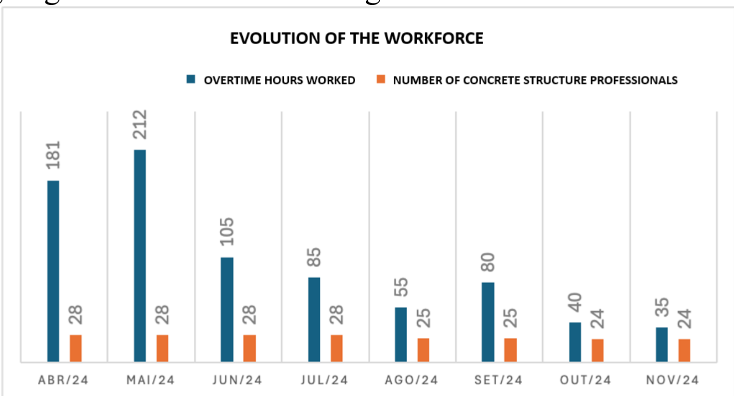

Figure 12: Evolution of the workforce

Finally, the active participation of workers in the continuous improvement process, through their involvement in planning and implementation meetings, was a decisive factor in the early identification and resolution of issues. This collaboration allowed for problems to be addressed before they became significant obstacles, improving problem anticipation and subcontractor reliability. By implementing control systems such as Kanban and SW, clearer and more efficient processes were established, resulting in greater reliability of subcontractors. Overall, these strategies not only improved project execution but also laid the foundation for the long-term sustainability of improvements in future projects.

The results show benefits like increased productivity, reduced waste, and improved worker satisfaction, but also present challenges and limitations. Implementation challenges include resistance to change, as workers may be hesitant to adopt new methods and be monitored. Additionally, training is necessary for successful implementation, along with continuous adjustments to practices. Coordination complexity arises when multiple teams are involved, as delays between teams can disrupt workflow.

There are also limitations, such as the sustainability of improvements, as gains may not carry over to future projects without strong institutionalization and could be affected by staff turnover or management changes. The cost of implementation may be a barrier, especially for smaller companies, due to initial expenses for training and tools. Furthermore, the findings may not be generalizable to all projects, particularly those with high uncertainty or unstable production processes.

Broader implications include enhanced worker well-being, as reduced overtime and improved working conditions can increase satisfaction and reduce turnover. This, in turn, can contribute to workforce stability. A long-term cultural shift is possible through active worker involvement in continuous improvement, fostering a more collaborative organizational culture. Additionally, optimizing resources and reducing waste supports more sustainable practices, although more effort is needed to track environmental benefits. SW practices have the potential for broader application in other construction types and processes to achieve efficiency gains.

Finally, the success of SW depends on ongoing monitoring and adjustments as project variables change, requiring constant engagement from workers and managers. The use of visual management tools and progress tracking also relies on accurate data and technological infrastructure, which may be challenging in less digitally equipped environments.

CONCLUSIONS

The implementation of SW in the concrete structure of the residential project improved operational efficiency and reduced process variability. Standardizing operations with the production team enabled the creation of SW elements tailored to the construction context. Strategies such as defining execution sequences, assembling standard kits, and applying visual management helped reduce time and resource waste. Activity mapping showed less time spent on non-value-adding tasks like waiting and movement, enhancing labor and equipment use. This stability improved productivity, planning adherence, and reduced rework. The implementation roadmap reinforced SW as an effective tool to control and minimize inefficiencies.

Beyond operational benefits, SW positively impacted worker well-being and working conditions by redistributing activities and improving time management, reducing overtime, and promoting a higher quality of life for the team. Organizational climate surveys revealed increased worker trust in the company and improved conditions, laying the foundation for sustainability in future projects.

While the study demonstrates the significant benefits of SW in improving construction efficiency, challenges such as worker resistance, coordination complexity, and sustaining long-term results must be addressed. SW also suggests a broader cultural shift in project management and offers a model for other industries aiming to optimize workflows, reduce waste, and improve working conditions. Its adaptability across different project scales and types is crucial. Although SW shows strong potential in large, predictable projects, its use in smaller or more variable ones may require tailored adjustments. Future studies should explore how to adapt SW practices to ensure effectiveness in diverse construction contexts.

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