KAIZEN AS AN IMPROVEMENT METHOD FOR CONCRETE WALLS CONSTRUCTION IN SOCIAL HOUSING PROJECT

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ABSTRACT

Making production processes stable is the basis of the Toyota Production System (TPS) for improving processes and consequently of increasing the value of production activities. Hence, the set of tools based on the TPS that can be used within the kaizen approach emerges as an opportunity to seek to optimize processes and to increase productivity. The research points out the possibilities of improving production processes in social housing projects through the implementation of structured kaizen events. This article describes the implementation of kaizen events developed in a Brazilian company that constructs residential buildings with a focus on standardizing and stabilizing the process for producing the structure of buildings with a concrete wall typology. The methodology used to develop this study is action research. Based on a kaizen methodology structured in four stages: Definition and preparation; Execution; Monitoring and standardization; and support, the main steps that form the process of building concrete walls were analyzed. The main results obtained are flow improvements in the main stages that make up the construction process, a reduction in the workload and a contribution to reducing and adhering to the total lead time in the concrete wall stage, in addition, providing a reference for structuring kaizen events in the construction environment.

KEY-WORDS

Kaizen, Stabilization, Concrete Wall, Last Planner System

INTRODUCTION

The construction sector is commonly analyzed and criticized for its performance and for its various problems. The causes of these are the object of studies and research at the levels of product, of the production of projects and of the industry as a whole (Vrijhoef and Koskela, 2005). In an increasingly competitive market, implementing a lean production philosophy focused on reducing stock, optimizing time and process and

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product quality and reducing the price becomes decisive for the success of organizations (Bordin et al. 2018). In its simplest form, lean production is about eliminating waste or efforts without added value in a company and, in the essence of its concepts, this is sought by taking initiatives that prompt the continuous improvement of processes (Ortiz, 2010).

The factors that guide the continuous improvement of processes were introduced based on presenting a scientific model for implementing improvements that are founded on a sequence of questions that focus on identifying, analyzing and solving problems, called the Scientific Thinking Mechanism (STM) (Shingo, 1987; Shingo, 2010). Imai (1986) spread the concepts of continuous improvement in management in the West using the term kaizen, the Japanese word for "continuous improvement". Kaizen involves all employees of a company, who focus on improving processes (Ortiz, 2010).

In the field of civil construction, the institutionalization of a culture of kaizen or the continuous improvement of processes is marked by initiatives such as measuring and monitoring processes, defining the desired objectives clearly, standardizing the best procedural practices and always seeking to improve them, and finally, by delegating responsibility for improvement to all those involved (Koskela, 1992).

Thus, some initiatives regarding structured kaizen practices initiatives have been developed in the construction industry. Rybkowski and Kahler (2014) approach the theme of games and simulations to illustrate the basic concepts of continuous improvement and standardization; Bordin et al. (2018) explore the A3 tool in the kaizen process of a company that assembles metallic structures; Tezel et al. (2018) seek to understand the execution of cells of continuous improvement, with its associated benefits and challenges, in the supply chain of highways in the United Kingdom; Vivan et al. (2016) present a proposal for a model for developing kaizen projects aimed at the construction sector with a focus on housing.

However, as commented on by Berndtsson and Hansson (2000) and Brunet and New (2003), a *kaizen* methodology, and therefore the techniques and tools used in its development, can be adapted and transferred to the circumstances and characteristics of each company or sector.

In this context, this work presents the possibilities of improving processes in civil construction, in social housing works through the approach of structured kaizen events. By conducting action research at a construction site of a Brazilian construction company, this article puts forward the process for making the production of concrete walls more stable by applying a *kaizen* methodology.

LITEARATURE REVIEW

LEAN CONSTRUCTION AND THE LAST PLANNER SYSTEM

The civil construction sector has looked to the manufacturing industry in search of solutions to minimize its problems (Pereira and Cachaldinha, 2011). The Toyota Production System (TPS) in its essence focuses on eliminating waste and increasing value for the customer (Ohno, 1988). In the early 1990s, the concepts and ideas that guide the basis of the TPS were adapted for the construction industry, giving rise to what we know today as Lean Construction.

Lean Construction, the production philosophy for construction proposed by Koskela, is based on principles that serve as a basis for reducing wastes and improving the efficiency of the production system. Complementarily, Ohno (1988) adds that the basis of a production system is to provide stability for carrying out operations.

Thus, the Last Planner System (LPS) has emerged as a technique for controlling production, providing basic stability and generating conditions for introducing advanced lean concepts (Viana et al. 2010).

In this system, long-term planning focuses on global objectives and constraints, contemplating the project as a whole and providing guidance on what should be done. At a lower level, medium-term planning, specifies the means to achieve these objectives, identifying and removing constraints restrictions, looking ahead 6 weeks and ensuring that the necessary materials, information and equipment are available so that the activities can be performed (Ballard, 1994). Finally, the system can improve the reliability of short-term assignments, protecting the planned work from variability and looking for the commitment of the workforce through the actions of the work teams that decide what will be performed (Ballard, 1994).

KAIZEN

The term kaizen is an expression of Japanese origin, formed from "Kai", which means to modify, and "Zen", which means for the better. (Martins and Laugeni, 2005). The essence of kaizen means continuous improvement, involving all team members, including managers and workers of the production system (Imai, 1994).

For Sharma and Moody (2003) the philosophy of kaizen is supported by improvements in work processes by means of initiatives that seek to eliminate wastes by using inexpensive solutions that are supported by the creativity and motivation of work teams.

Kaizen events have often been implemented for targeted improvement actions, carried out with the support of cross-functional teams focused on improving a specific work area, pre-determined objectives, and accelerated deadlines (Farris et al. 2008). In this context, in a short period of time (between 3 and 5 days), teams involved in the kaizen event focus their attention on solving problems by using low-cost tools, to develop and implement improvements in specific areas (Farris et al. 2008).

Therefore, kaizen teams can identify and tackle problems that oblige companies to work with high levels of waste. However, although the methodology is simple, it needs a lot of determination to succeed, as it represents a change in the company's culture (Graelm and Peinado, 2007).

Imai (1996) suggests that for kaizen implementations to result in problem-solving based on evaluating data, to facilitate the communication of problem-solving processes and to keep the kaizen culture active in organizations, the application should be structured in eight steps:

1. Choose the theme/focus of the application (determined according to administrative policies according to priority, importance, urgency or economic situation);
2. Analyze the context;
3. Collect and analyze data to identify the root cause;
4. Establish countermeasures based on data analysis;
5. Implement countermeasures;
6. Confirm the effects of countermeasures;
7. Establish or revise standards to prevent recurrence;
8. Review the previous processes and start working on the next steps.

Finally, is shown in the IGLC literature an important contribution from Rybkowski and Kahler (2014) that brings the outcomes for a new simulation that illustrates the productivity potential of collective kaizen and standardization. They investigate how collective kaizen and standardization can be made part of the daily process fabric of lean construction processes bringing new improvement opportunities (Rybkowski and Kahler (2014).

RESEARCH METHOD

DESCRIPTION OF THE METHOD

The development of this study was carried out through an action research, due to the characteristics and contexts presented. This methodology presents an empirical basis associated with the process of solving a collective problem, and researchers and participants of the problem involved in an operative way (Thiollent, 2011). For Tripp (2005) this methodology is defined as any continuous, systematic and empirically based attempt to improve practice. The main features. In addition, aspects related to the participation and intervention of those involved, process documentation, an oriented proactivity and the continuous search for problem solving are observed as characteristics (Tripp, 2005).

Thus, throughout the study, researchers acted in a participatory and active way in the generation, collection and analysis of information. During the stages, data were collected through photographic records, documents and spreadsheets, containing information on the execution flows, number of operators and execution times of activities.

DESCRIPTION OF THE COMPANY AND CONSTRUCTION SITE

The study was carried out in a company in Brazil that was founded in 1979 and that has been working in the residential construction sector, in the construction and incorporation of medium standard projects and projects with a focus on social housing. It operates on the national scene with an average of 230 projects per year. The construction company is certified by ISO 9001/2000 and PBQPH (Programa Brasileiro da Qualidade e Produtividade do Habitat – Brazilian Program of the Quality and Productivity of the Habit), – Level A.

The project analyzed in the study consists of medium standard residential buildings, located in the city of Fortaleza - Ceará. The development consists of two towers, with 224 housing units, distributed in 3 different typologies. The work began in May 2021 and is scheduled to take 25 months to complete.

Figure 1: Illustration of the project and how it will be implemented (provided by the case study company)

THE LEAN APPROACH IN THE CONSTRUCTION COMPANY

The construction company began to implement the Lean Approach in September 2020 by seeking to understand the concepts and carrying out the first implementation at a pilot works. From there, a process of disseminating Lean was initiated within the company, the model being extended to another 20 construction sites.

Currently, implementation has grown and has become a strategic project within the company's production sector. The focus of the project is to implement Lean Construction concepts in a progressive and sustainable way. Hence, planning is developed based on the Last Planner System and on a stable and standardized production rhythm for all activities that take place in the apartments. Thus, the flow and the standard sequence of activities are maintained, and defined to meet a standard takt time.

Having consolidated a structure of long, medium and short-term routines, the project now seeks actions for continuous improvement by holding kaizen events, where the challenge is to reach the production rhythm defined with the structure team.

KAIZEN EVENT STEPS AND RESULTS

To carry out the kaizen event, choosing a construction works was based on the level of maturity of Lean implementation that the company had reached. Figure 2 shows the steps of the Kaizen event implemented in the study.

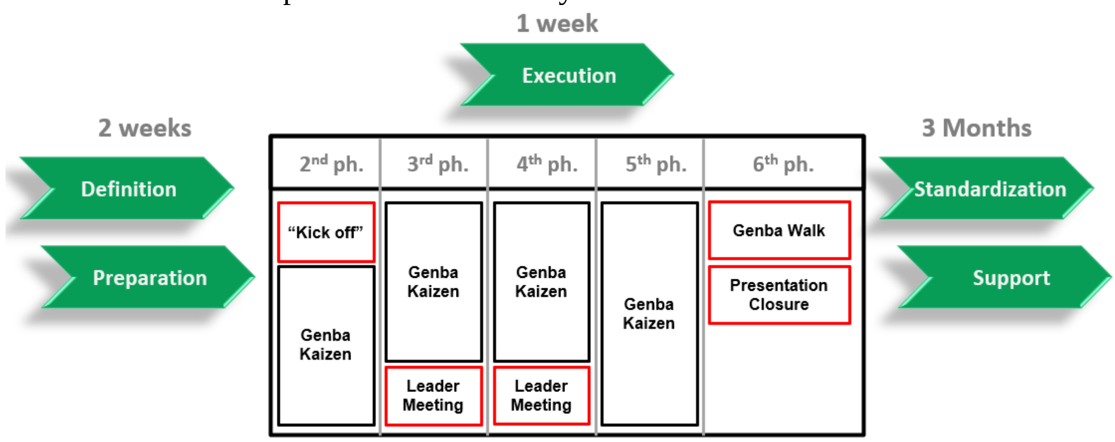


Figure 2: Execution steps of the Kaizen event (the authors)

DESCRIPTION AND PREPARATION

The process chosen to carry out the kaizen event was identified from the information collected by the production team. It was attested that building the concrete wall was not performed as expected by the macroflow that the company had standardized. It expected this step to be carried out in 4 working days, and the work was maintaining an average lead time of 5 working days. In addition, the high impact of the process on the organization's production system was decisive for choosing this process.

Process and information flow

From the definition of the production process, each of the activities that compose it were mapped and a mapping was carried out in a collaborative way with those in charge of each of the stages of producing the concrete wall. The activities of each step were sequenced and the process for doing this was described using a swimlane flow chart.

The sequence of building the concrete wall comprises the stages of marking, scaffolding, installations, formwork and concreting. This comprises a total of 38 activities, carried out by 6 production teams consisting of 54 employees of different functions, bricklayers, unskilled laborers, electricians, plumbers and assemblers.

Current Status (Description of problems) and need for kaizen

The field analysis and the sequencing of activities carried out with the field teams indicated that the main process problems were the interference between service fronts (Operators); interference between product and tooling; difficulties in moving materials, the use of defective tools and wastes being created due to movement, rework and wait-time.

As actions to improve and address the problems presented in the production process, proposals for improvements were defined involving the creation of the following items:

- Process Capability Framework;
- Operator Balancing Chart;
- Standardized Work Diagram;
- Definition of takt time by activity;
- Creation of supply routes/windows;
- Define Supply Standards;
- Management at sight;
- Application of continuous flow;
- Creation of Pull System where necessary.

EXECUTION

The execution stage was marked by holding a kaizen event focused on stabilizing the marking, scaffolding, installation, formwork and concreting processes.

Survey of opportunities

The members of each of the production teams responsible for carrying out the steps were invited to talk about their difficulties in carrying out daily activities and to present possible proposals for improvements to the process as a whole. The information collected in this step was structured by means of a prioritization matrix (impact vs effort). As a result of this stage, 86 improvement actions were proposed in an interactive and collaborative way. These improvement initiatives will be implemented and monitored by the construction management team using a document called the kaizen journal.

Kaizen Journal				***Status***					
Item	*Problem or Fact*	Idea	Who	When	25	50	75	100	Remark
63	Electricity boxes – Narrow Rooms	Define the height of the low box	VERAS	17/11/21					MOLD
64	Concreting materials above the beam	Check exactly what the materials are that lie above the beam and define a fixed place for them	TALYS	17/11/21					SCAFFOLDING
65	Different production between works		LARISSA	12/11/21	OK	OK	OK	OK	SCAFFOLDING
67	Turner	Insist on delivery	LARISSA	19/11/21					SCAFFOLDING
69	Heavy hose	Implement spider	ALEXANDRE	11/11/21	OK	OK	OK	OK	CONCRETING
70	Poor quality of the concrete	Aligned with Polimix	POLIMIX	11/11/21	OK	OK	OK	OK	CONCRETING
71	Hard concrete makes descent difficult	Aligned with Polimix	POLIMIX	11/11/21	OK	OK	OK	OK	CONCRETING
72	Delay of concrete	Definition of 5 trucks	POLIMIX	11/11/21	OK	OK	OK	OK	CONCRETING
73	Truck short	Definition of 5 trucks	POLIMIX	11/11/21	OK	OK	OK	OK	CONCRETING
75	Cleaning more difficult in the part above the façade – vap Position		POLIMIX						CONCRETING
80	Hall lighting	Piu in a mobile reflector	POLIMIX	16/11/21					SCAFFOLDING
83	Priority in the ascent of the climbing mold	Speak with the crane operator	LARISSA	17/11/21					SCAFFOLDING
85	Broken spacer – beam	Abir agilis	LARISSA	17/11/21					SCAFFOLDING

Figure 3: Kaizen journal developed based on workers' suggestion (the authors)

Production process alternatives

The managers involved in each of the 5 stages were divided into working groups to analyze the process. The Seven Ways scenario and layout analysis tool was used to simulate and propose different execution flows of the production stages. The alternatives proposed by the work teams were presented and evaluated in a collaborative way, giving rise to new process flows for each of the stages of building the concrete wall. The groups were divided to meet the standard macroflow following the main macro steps: Marking, Scaffolding, Installations, Formwork and Concreting.

STANDARDIZATION AND SUPPORT

In this stage, the objective is to apply the improvements developed during the kaizen event so that they can be implemented gradually, focusing on improving processes, reducing lead time, optimizing teams and on the consequent stabilization of conducting the stage of building a concrete wall.

Hence, proposed improvements are in the phases of implementation and evaluation so that then new standards can be established for the execution process. However, from the first data collected, indications of good results can be detected when analyzing the activities.

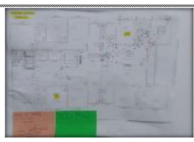
Step	Current Layout	Current situation	Problem	Actions / Impact	Proposed layout
 Marking out		Activities being performed sequentially	Carrying out marking activity takes a long time	The activity of fixing the spacers will be done in parallel with the witness, thus reducing the total time by 40 minutes	
 Framing		The activities are done in large batches of production.	It takes a long time to assemble the framing	Application of the principle of continuous flow in the activities of fixing the screens, corner screens, reinforcement and spacer. 40 minutes reduction in time. Making it possible to reduce the total time of the framing + installations by 4 hours	
 Installations		The activities are carried out in large production batches.	High turnaround time for installation.	Application of the principle of continuous flow	
 Mold (Assembly)		Activities being carried out non-sequentially	High amount of time taken to do the activity of mounting the mold	Creation of work teams by block of activities with the crew working in line (disassembly, transport and assembly of the mold)	 
 Concreting		The activities are carried out in excess	High amount of time taken to do concreting	Concreting points changed from 13 points to 9 points. And total time reduced by 2 hours	

Figure 4: Scenario analysis using the Seven Ways tool (the authors)

Process benefits, reduction in cycle time and teams optimization

Table 1 presents the partial results collected from the improvements proposed during the kaizen event. With regard to the processes, changes in the personnel responsible for conducting some activities, changes in the sequencing and reducing production batches provided a better integration between the work fronts, thereby reducing waiting time losses and prompting flow improvements in the process.

The reflection of the process improvements has been translated into reducing the cycle time of various activities in the construction process. On the day before the concreting stage, activities such as axis transfer and marking had a cycle time reduction of at least 50% in their execution process. In the formwork assembly stage, activities considered critical, such as assembling the outer part of the formwork, achieved an average reduction of 30% in cycle time.

For the steps carried out in the concreting, the impacts on the cycle times were mainly reflected in the activities related to the framing stages and the 2nd stage of the formwork, respectively, with reductions of 14% and 32% in the average execution time performed previously. In addition, activities related to the installation and concreting stage also obtained time gains after the proposed changes.

The impact of these cycle time reductions resulted in reducing the average lead time for executing the process for building the concrete wall as a whole. Although the results are still initial, the number of the last 10 concretings reveal that the average lead time fell from 4,8 days to 3,9 days, approaching the ideal lead time of 4 working days.

PLANNING THE STEPS OF BUILDING A CONCRETE WALL			
1 DAY BEFORE CONCRETING	STEP	AVERAGE REDUCTION OF THE TIME CYCLE (%)	GAINS IN THE PROCESS
	TRANSFER OF AXIS	-67%	BEFORE: Activity was done by the marking team. NOW: Activity done by the topography team.
	MARKING OUT	-50%	NOW: Marking team transports the materials from 07:30 until the liberation of the topograph. BEFORE: A lot of materials present at the work station (beam) generated losses by waiting, thus increasing the time to do the work.
	INTERNAL MOLD - 1ST PHASE	-	-
	EXTERNAL MOLD	-30%	NOW: Starting with the alignment of the crane, there was a reduction in the transport time from the facade.
DIAY OF CONCRETING	ACTIVITY		GAINS IN THE PROCESS
	FRAMING	-14%	The Flow of activities improved and the sequencing of the framing with the installer was observed with the real gain. The sequencing of the framing with the installer was the real gain.
	INSTALLATIONS	-10%	
	INTERNAL FORM - 2nd PHASE	-32%	Prioritizing the facade of the twinned apartments reduces the number of closure activities for the following day.
	CONCRETING	-36%	When the number of conctete-mixer trucks is adequate and the concrete is within the receipt criteria, concreting flows rapidly.

OBSERVATIONS
1) THE IRONWORK TEAM AND INSTALLER INTERRUPT THE CAGE TO START THE FRAMING AND INSTALLATIONS OF THE BEAMS WHILE THE SERVICE IS BEING LIBERATED.
2) RAISE THE CLIMBING SCAFFOLD ON THE SAME DAY AS THE FACADE.
3) CHECK POSSIBILITY OF THE PRODUCTION BEING BY AREA.

Table 1: Impact by stage on the cycle time of the improvements implemented (the authors)

Finally, the improvements implemented made it possible to reduce the number of teams performing the framing and formwork stages, causing a decrease of five skilled workers in these teams as its presented on Table 2. In addition, a rearrangement of the concreting team could be carried out, thus replacing a skilled with an unskilled worker. These changes were reflected in the scaffolding, formwork and concreting teams and generated savings opportunities of approximately 18% in the labor costs of the process of building concrete walls.

The next steps in this stage are to formalize the actions proposed in the kaizen that result in process improvements due to structuring clear work instructions, and that enable each activity of the steps involved in the process of building concrete walls to be better understood. In addition, support initiatives such as feedback from the kaizen journal, training, and the presentation of changes after the kaizen is carried out, must be developed so that the teams involved in the event maintain the culture of continuous improvement in the company and can replicate the process improvements in the company's other production units.

ACTIVITY	POST-KAIZEN FUNCTION			MODIFICATIONS
	SKILLED	SEMI-SKILLED	UNSKILLED	
SCAFFOLDING	**-18%**	-	-	REDUCTION OF 2 SCAFFOLDERS
INTERNAL FORM	**-11%**	-	-	REDUCTION OF 3 ASSEMBLERS
CONCRETING	**-50%**	-	**50%**	REPLACE ONE SKILLED WORKER WITH ONE

Table 2: Impact by stage on the production teams (the authors)

DISCUSSION

The implementation of the kaizen event related in the study took place over 5 days with the involvement of a multidisciplinary team responsible for executing the selected process, which corroborates what Farris et al. al. (2008), about the process of implementing kaizen events requiring a concentrated effort in a short space of time.

However, it is essential to highlight that the result the kaizen event is the result of a structured process initiated previously before the execution of the event itself, and involves the selection of the topic studied, the analysis of the context in which the problem is inserted and finally the data collection and evaluation (Imai, 1996). In this sense, the preparation stage was developed over two weeks prior to the event, where the theme of stabilization of the concrete wall process was defined based on the lead time data collected and the high relevance of the process for the work.

In a complementary way, another fundamental point for the success of the event is that the essence of continuous improvement proposed by kaizen is based on the involvement of everyone on the team (Imai, 1994). Sharma and Moody, (2003); Farris et al., (2008) point out that the implementation of kaizen events is marked by the identification of waste and problem solving based on the involvement of teams and low-cost creative solutions. From this, as shown in Figure 3, the demands raised by the production teams were structured by evaluating not only their impact within the production process, but the level of effort spent on implementing the actions.

Following the steps proposed by Imai (1996) throughout the event, several countermeasures or improvement actions were proposed, proposed through the seven ways tool, implemented by the production teams and validated or rejected by the kaizen team. As shown in tables 1 and 2, the first data point to good results in terms of time, cost and workload indicators (18% reduction for scaffolgind, 11% reduction for internal form, and 50% reduction for concreting) . However, it is necessary to continuously monitor the actions and validate the improvements developed in order to define new process standards, avoiding the recurrence of the listed problems and establishing together with the work teams behaviors that provide a change of culture in the organization (Imai, 1996; Graelm and Peinado, 2007).

In addition, in the context of Lean implementation in which the company is inserted, the problem solving culture and the concepts of continuous improvement stimulated from the implementation of kaizen events prove to be strong allies in the consolidation of the implementation of the lean construction philosophy (Rybkowski and Kahler, 2014).

Finally, the literature suggests several paths and routes for the realization of kaizen events, however it is important that these implementations take into account the scenario of the organizations in which they will be inserted. In this way, understanding the context and developing an event structure suitable for each situation can be decisive for the consolidation of the concepts of continuous improvement. As Rybkowski and Kahler (2014) concluded that collective kaizen events can bring the improvement outcomes and place for standardization, the current kaizen event shown the Company a new way to improve production process trough lean methodologies.

CONCLUSIONS

The current implementation was effective as it managed to promote a culture of improvement based on the engagement of all team members involved in carrying out the stages of the process studied. The participation of the production teams provided a detailed understanding of the activities and generated future opportunities for further improvements. Therefore, it is important to highlight the importance of the support of managers and coordinators, in addition to the commitment of the workers involved in the event.

The preliminary results indicate that the proposed improvement actions are contributing to stabilizing the process for producing concrete walls, to the extent that process flow improvements, reductions in activity cycle times and the rearrangement of teams are reflected in matching the lead time taken to what the company desired.

The next steps of the study are to develop a standardized working procedure for the concrete wall process comprising the steps covered in this study. Furthermore, considering that a research action where the researchers are involved in the implementation of the full Lean Construction project, and since the kaizen methodology is part of the implementation path of this project developed by the company, the structuring of a methodology for carrying out standard kaizen events, focusing on the stabilization of construction processes, is addressed and will be conduced as pilot implementation. Activities performed at the event can serve as a reference for implementing a new kaizen focused on stabilizing other production processes carried out by the company, such as: ceramics, painting, and roofing.

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