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EXPLORING THE USE OF DIGITAL VISUAL MANAGEMENT FOR LAST PLANNER SYSTEM IMPLEMENTATION

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ABSTRACT

The Last Planner system has been widely implemented seeking to offer greater transparency and predictability for construction projects through collaborative production planning. A major challenge in this context is increasing process transparency, which is one of the visual management (VM) purposes and a basic principle of the Lean production philosophy. Achieving this has required extrapolating the limits of the physical environment through the use of digital tools, which lead to the digitalization of VM and to virtual collaboration. This process was accelerated due to the COVID-19 context, the physical boundaries constraints, and the need for real-time information sharing and collaboration. This paper aims to explore and discuss the use of digital VM tools for LPS implementation. Action research was the methodological approach adopted in this research. The investigation was based on a consultancy in a construction company in Brazil. The digital VM tools and practices adopted in the different planning levels were assessed through requirements considered relevant to this context, including visual and non-visual aspects. Their impact in collaborative production planning is discussed. The ongoing results indicate that digital tools were better suited to the strategic and tactical levels, while traditional tools showed more suitable for the operational level.

KEYWORDS

Last Planner® System, Visual management, Collaboration, Digitalisation, Miro

INTRODUCTION

Last Planner® System (LPS) is one of the main tools and methodologies used for the implementation of Lean Construction. Developed by Ballard and Howell in 1992, LPS is a collaborative planning methodology for production control in construction projects. LPS makes detailed plans by those who execute the work, including all hierarchical levels of the project, seeking to reduce waste and increase planning and workflow reliability (Ballard and Tommelein, 2016). This methodology proposes workflow control with a planning system that tells what should-can-will be done in different planning levels, continuously learning over the production process (Ballard, 2000).

LPS employs Visual Management (VM) to provide a structure for collaboration and coordination of information in the planning levels in a transparent way (Erazo-Rondinel

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et al. 2020). VM is an important management strategy and a fundamental element of Lean Construction that creates highly visual information fields from which people can pull information for an improved self-management and control (Tezel et al. 2013). The purpose of a visual control for a production system is to provide clear visual indicators depicting the status of the system at an appropriate level for the audience to achieve shared understanding so that necessary actions can be taken (Ballard and Tommelein, 2016).

Traditionally, LPS is implemented through the concept of "Big Room", also known by the Japanese word “Obeya”, where collaborative planning meetings are held, milestones plan, pull sessions, weekly meetings, and daily stand-up meetings (Pons, 2019). For this, post-its, whiteboards and colorful pens are used to facilitate VM.

From 2020, the onset of the COVID-19 pandemic has forced production environments (the construction domain included) to become more sensitive regarding the safe working environment (Stiles et al., 2021; Wu & Wang, 2020), leveraging and valuing the use of digital technologies in construction. Recently, some traditional VM tools and Lean Construction techniques have been converted into IT-based prototypes (Sacks et al, 2010a; Dave et al, 2014) in order to fulfil this digitalization demand. Also, Lean construction and VM have been supported by the actively use of IT tools that collect construction field data (Barbosa et al. 2013, Kirchbach et al, 2014) and increase the quality of data (Dave et al. 2008), providing up to date information about the construction sites. However, this process of migrating from traditional to digital approaches can bring challenges in maintaining the operational requirements of the tools. In this sense, the VM role of continually communicating with all participants in a visible and comprehensible way (Koskela, 2000; Formoso et al. 2002) should be maintained in digital tools.

The main objective of this paper is to explore the use of digital VM tools through the implementation of the LPS. It describes the process of Lean Construction implementation in a housing construction company in Brazil in 2021 during the Covid-19 pandemic period, where traditional and manual tools were replaced by digital VM tools. These digital VM tools were assessed toward several existing requirements from the literature. The benefits and challenges of its implementation were identified, considering a scope of analysis that was limited to the construction phase of housing projects.

VISUAL MANAGEMENT

VM can be defined as a management system that attempts to improve organizational performance through connecting and aligning organizational vision, core values, goals, and culture with other management systems, work processes, workplace elements, and stakeholders, by means of stimuli, which directly address one or more of the five human senses - sight, hearing, feeling, smell and taste (Liff and Posey, 2004; Tezel et al. 2009). These stimuli communicate quality information such as necessary, relevant, correct, immediate, easy-to-understand, and stimulating, which helps people make sense of the organizational context at a glance by merely looking around (Greif, 1991).

Tezel et. al (2016) defined the main purpose of VM as increasing process transparency to promote improvements in the production systems and the overall management of organizations. Process transparency can enable decision-making by supporting increased employees’ participation and involvement in the process (Klotz et al. 2008). Visual approaches can support information accessibility, availability of real-time data collection and processing (Dallasega et al. 2018), and help to improve the understanding of schedules through the availability of information (Tezel and Aziz 2017).

The use of digital technologies in construction are bringing new opportunities regarding the capture, test, verification, and validation of information, as well as the support of management, construction, use, operation, and maintenance processes (Chen and Kamara 2008; Tezel et al. 2016; Koskela et al. 2018). The high level of information transfer in construction project management is a major challenge even with technological developments. Keeping information simple, straightforward, and accessible is at the heart of reliable planning (Tezel and Aziz 2017). Digital technology has contributed to extending the range of VM applications, improving (a) visibility by improvement of interface innovations; (b) temporal capacity by greater information gathering, storing, and analysis; (c) problem-solving capabilities due to the automation of information processing, and (d) geographical capacity through high connectivity (Murata 2018).

Constructs related to the adoption of Digital VM systems are presented in the literature in a dispersed way. However, Pedo et. al (2020) propose and discuss a set of digital VM constructs in a design management environment. The scope of the analysis was limited to highways and railways design projects. The constructs are: (i) simplicity of functioning; (ii) information standardization; (iii) autonomy to plan and control; (iv) right amount of information available; (v) easy information accessibility; (vi) flexibility; (vii) information traceability. Those constructs were adapted to the context of the present research in order to assess the digital VM tools used in a LPS implementation and will be better discussed throughout the paper.

RESEARCH METHOD

The investigation was based on a consultancy project undertaken under an eight months period in a construction company in Brazil, named Company A. Company A is a real estate and construction company based in South Brazil with 19 projects under development, which consist of 5.965 residential units. The company has been proposing a transformation of the organizational culture through the development of a Lean-based Production System and consistent, sustained efforts on innovative and digital projects. In this context, Company A started a Lean implementation with the Consultancy Company based on pilots implementation in 2021. The pilots were mapped to assist four construction sites built in conventional construction methods - concrete structure and mortar. The four low-income housing projects have similar characteristics, including location, number of buildings and apartments, and units' area. This research consisted of a critical analysis of the digital VM tools implemented in Company A to support LPS implementation in different planning levels.

Action research (AR) was the methodological approach adopted in this investigation. AR focus is on solving real problems (O'Brien 1998) and contributing to the organization's development, focusing on simultaneous action and research in a collaborative manner (Coghlan and Brannick 2001). According to O'Brien (1998), AR is adopted when circumstances require flexibility, involvement of the client, or change must take place quickly or holistically. The research was conducted through multiple iterative cycles of diagnosis, planning action, taking action, and evaluating action (Figure 1), with different levels of complexity (Coghlan and Brannick 2001), regarding different planning levels. This structure follows the cyclical, iterative, and repetitive nature of AR.

The study was divided into five cycles (Figure 1, Table 1). The first cycle, **Current State**, was held before starting with the LPS implementation in order to understand and analyze the deficiencies in the current production process context in the company. The findings were prioritized by the clients to define the next steps and actions. **Cycles 1, 2, 3, and 4** describe the LPS implementation in four construction sites, or pilots, and the digital VM tools used in the process. Those were held in four weekly AR cycles each of diagnosis (D), planning action (PA), taking action (TA), and evaluating action (EA), based on AR approach (Coghlan and Brannick 2001) and common to Plan-Do-Check-Act (PDCA) cycle (Shewhart and Deming 1939).

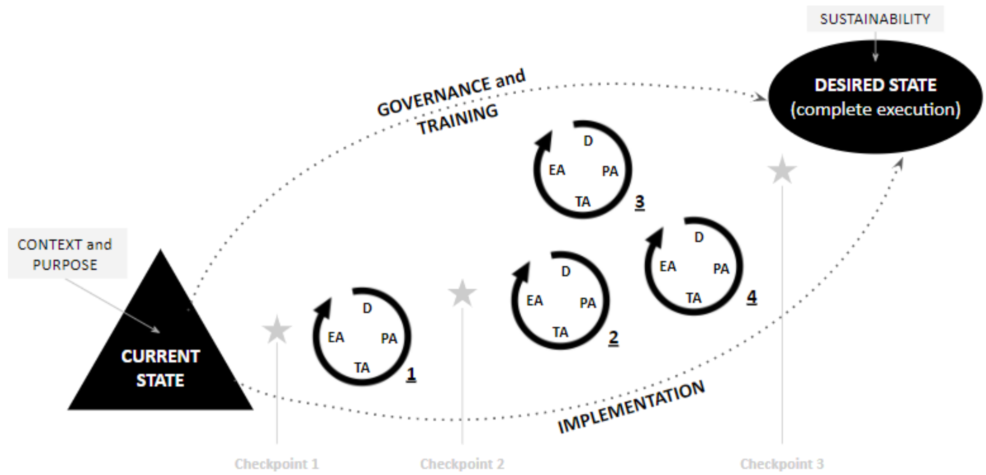

Figure 1: Multiple iterative cycles of AR, based on Coghlan and Brannick (2001).
Legend: Diagnosis (D), Planning Action (PA), Taking Action (TA), Evaluating Action (EA)

Each cycle of implementation was improved by applying the lessons learned and avoiding the mistakes made in the previous cycle. Throughout those cycles, an online training course and "knowledge drops" through classes in the construction site were held in order to change traditional patterns that were not aligned to the Lean Construction philosophy. This cyclic process in each pilot was repeated until achieving the understanding of the LPS and changing old patterns. The general goal was to create a simple, repeatable process of iterative learning, evaluation and improvement that would lead to increasingly better results for the practitioners, such as predictability, financial health, physical progress adhering to the plan, collaboration and motivated team.

Check-points were realized (Figure 1) in the company following Coghlan and Brannick (2001) recommendations of (a) systematically generating and collecting research data about the ongoing system; (b) engaging with others in reviewing the data generated and collected; (c) conducting a collaborative analysis of the data; (d) planning and taking collaborative action based on shared inquiry; and (e) jointly evaluating the results of that action, leading to further planning. Lastly, the adoption of digital VM tools and practices in the different planning levels to support the LPS implementation was evaluated through requirements developed by Pedó et al. (2020). Their impact in collaborative production planning were discussed.

Data was collected using multiple data collection techniques: (i) document reviews; (ii) 16 semi-structured and follow-up interviews with the main ten company departments; (ii) participatory and non-participatory observations attending all the implementation stages of LPS; (iv) individual and group discussions; and (v) plus and deltas. Using multiple sources of data and combining methods, as well as multiple projects, strengthened the AR study (Patton, 1990) and reached methodological triangulation. The results of these research phases were important for the consultants and researchers regarding the understanding of the company and their planning and control routines. The triangulation method supports the decisions and premises that were considered as ground for the current paper.

Table 1: Classification of tools in Traditional and Digital approaches

Phase	Tool	Diagnosis	LPS implementation			
		Current State	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Duration (weeks)			6	4	4	4
Context	Swimlane	T -> D				
	Findings prioritization	D				
Should	Sequence activities	D	T	T	T	T
	Line of Balance	D	T	T	T	T
Can	Lookahead		D, T	T	T	T
Will	PPC		T	T	T	T
Will / Did	Check-in		T	T	T	T
Did	Check-out		T	T	T	T
Continuous improvement	A3		D	D	D	D
Governance	Plus and Deltas	D				
	Agenda	D				

Legend: Traditional (T), Digital (D)

PROJECT PHASES

DIGITAL VM TOOLS ADOPTION IN LPS IMPLEMENTATION

The work structuring of the Lean Construction implementation in the company included a diagnosis followed by the LPS levels of planning, based on should-can-will-did (Ballard and Tommelein 2016): (i) master planning, used to set milestones and phase durations; (ii) lookahead planning, when constraints are identified and removed; (iii) commitment planning, in which promises are make reliable; and (iv) learning, using five whys to identify countermeasures, and act to prevent repetitive errors. The diagnosis is related to the **Current State**. The implementation of LPS levels of planning refers to **Cycles 1, 2, 3,** and **4**. A set of tools were used and refined in each of those phases in different projects to support the meetings, seeking to provide an environment that supports collaboration, employee engagement, and information management between the different planning and hierarchical levels of the construction sites. Before Covid-19, those tools had a mostly traditional approach, such as worksheets and manual boards on the walls with post-its.

The diagnosis (**Current State**) in company A was planned in five steps (Figure 2), including the main sectors of the company. **Workshop 1**, mapping the company's process through a Swimlane, was carried out in large panels with post-its. Swimlane diagram is conceived for process modeling, connecting a series of steps and concerns in pools and lanes in order of occurrence by the participants. Due to the risk of Covid-19 contamination and the geographic distance of some key members, the coordination defined that the next workshop should be held remotely. The consultancy company transferred the information from Workshop 1 to a digital version in MIRO and adjusted **Workshops 2** and **3** for the same context. MIRO (www.miro.com) is an online collaborative whiteboard adopted to facilitate the virtual and digital collaborative dynamics. This was the abrupt moment of change from traditional to digital due to the emerging needs of the context. The company quickly adapted to MIRO, with great team engagement. A specific blank board was sent before the official boards in order to introduce Miro and allow the team to test its functionalities for five minutes. This simple action accelerated the team's learning and avoided mistakes on the official board.

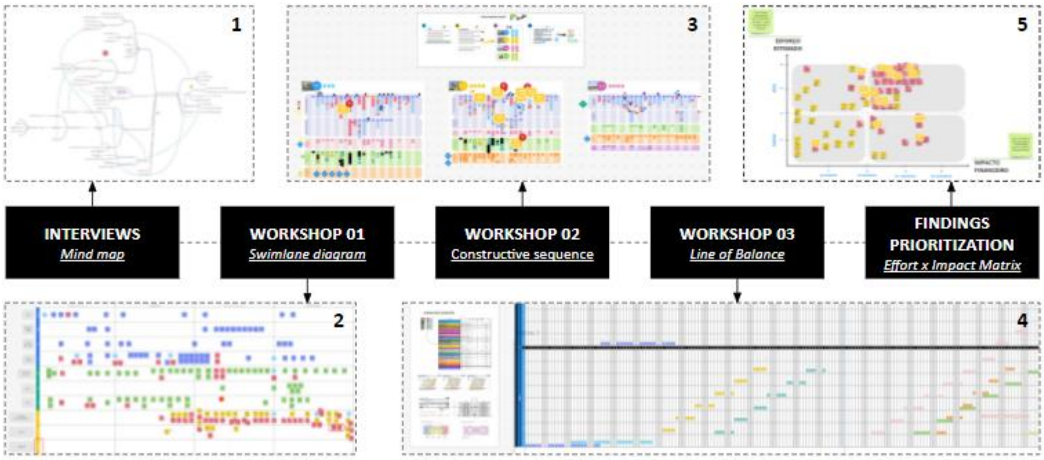

Figure 2: Digital VM tools from Diagnosis - Current State

A **findings prioritization** meeting was conducted with the different sectors in order to collaboratively design the results of the diagnosis, bringing a sense of ownership to employees and company's directors regarding the consultancy's interventions. The tagged post-its with opportunities for improvement should be positioned by the groups in real time in a matrix of financial impact versus estimated effort. The discussions resulting from this meeting served as the basis for defining the objectives and the next steps of the LPS implementation in the company.

Cycle 1 of the LPS implementation phase was carried out in the same construction project that served as the basis for the workshops (WS) 2 and 3 of the Diagnosis. Considering that the collaborative, digital and educational phase of the constructive sequence (WS2) and the line of balance (WS3) occurred in the diagnosis using MIRO, Cycle 1 ended up using traditional spreadsheets to test all possible scenarios for the line of balance and to define the pattern of the constructive sequence of that product. This process took two weeks to reach an adequate solution since it was the first pilot in the company and the product and construction standards were not well established yet.

Lookahead planning (Figure 3), with a twelve-week horizon, was built digitally for the first time using MIRO. All team members had access to the digital tool and could include constraints as they were identified, from anywhere. Implementing this weekly routine was challenging as the company did not have an established culture of anticipating problems and the young team had limitations in identifying possible restrictions. The constraints analysis and removal, breaking down tasks into operations and collaboratively designing those operations, was another weekly meeting realized in traditional spreadsheets in order to control performance metrics. Short-term planning tools were implemented in traditional spreadsheets and dashboards. **A3** tool, used for the improvement of some critical processes, was developed in MIRO, allowing all team members to access the digital tool all the time and track, record actions. **Cycles 2, 3,** and **4** had a similar structure, with the adaptation of the Lookahead planning from digital to traditional approach. In terms of governance, the recurring feedbacks with the team through the **Plus and Deltas** and the weekly **Agenda** were conducted in MIRO and were easily accessed and updated by lead members of the project. Although the tools maintained consistency and standardization throughout the cycles, each project went through its own stages respecting the uniqueness of each site development and team and promoting continuous improvement through transparency and collaboration.

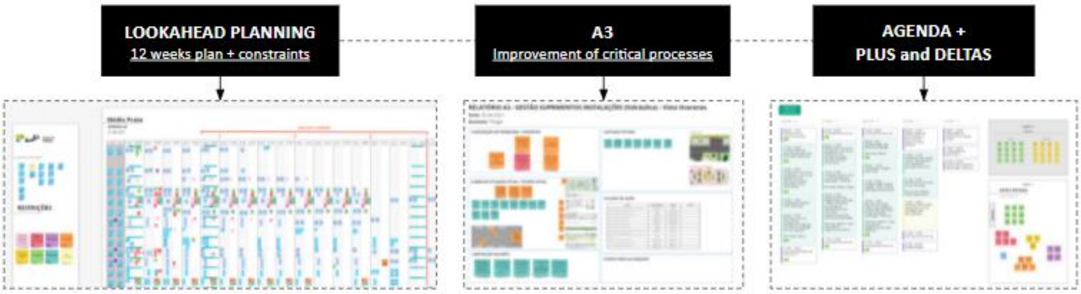

Figure 3: Digital VM tools from Cycles 1, 2, 3, and 4

RESULTS AND DISCUSSIONS

The use of MIRO and the digitalization of the workshops were the main Plus cited by the participants, highlighting the ability to make the meetings and discussions faster, keeping information and people organized, and its ease of use. Participants also mentioned the clear definition of the workshops' script and objectives, which were available for consultation throughout the meeting, in addition to the use of colors in the VM to help groups during the activities. The digital and virtual meetings carried out in MIRO with the support of parallel virtual rooms promoted the collaboration of a diverse group of employees from different locations. Furthermore, they facilitated the information to be quickly delivered and organized through friendly graphics, accessible and open to the participants who sparked their curiosity on the subject (Tufte, 2001). The tools started to be associated by the employees with learning initiatives and moments of reflection, helping to build communication rituals on the team. When it happens, the tools become important to people and relevant to the process (Valente, et al., 2019).

A Delta cited by the participants was the lack of automation of information between planning levels, with a manual pull of activities from the long to the medium and short terms. In this sense, the digital VM tools can be better explored in the company by the improvement of problem-solving capability considering the automation of information processing (Murata 2018).

The implementation of the digital VM tools was discussed and assessed by the authors based on constructs proposed by Pedó et al. (2020) for the design management phase, adapted to the operations phase context. Table 2 shows the classification of tools according to those constructs based on three levels of adoption (PEDÓ et al., 2020): adoption (A), partial adoption (PA), or non-adoption (NA). The four construction sites had a similar response regarding the VM tools implementation. The tools used in the Diagnosis, for Continuous Improvement, and for Governance can be classified as the most advanced as they adopt most part of the VM concepts (Table 2). In other respects, the tools from the four learning cycles of the LPS implementation planning phases lack the full attendance of almost all VM concepts, such as simplicity of functioning and easy information accessibility. Employees mentioned in the discussions and Plus and Deltas the simplicity of functioning, flexibility and communication as Miro main advantages, and automation as its main weakness.

The full adoption of the **Easy information accessibility** VM concept was not identified in any digital tool due to the lack of visual devices such as computers or television dedicated to an Obeya Room. This is harmful to achieve decentralizing decisions and to increase the degree of autonomy among production teams, indicated by Valente, et al. (2019) as a guideline for designing and implementing VM systems. In contrast, all tools had this concept partially adopted, showing its potential in this aspect with regards to geographically decentralized teams.

Table 2: Classification of applied digital VM tools according to VM concepts, based on Pedó et al. (2020)

Phase	Tool	Simplicity of functioning	Information standardization	Autonomy to plan and control	Right amount of information available	Easy information accessibility	Flexibility of tools	Traceability of information
Diagnosis	Swimlane	A	A	A	PA	PA	A	A
	Findings prioritization	A	A	A	A	PA	A	A
Diagnosis/ Should	Sequence activities	A	A	A	PA	PA	A	PA
	Line of Balance	NA	PA	PA	PA	PA	A	PA
Can	Lookahead	PA	PA	PA	PA	PA	A	A
Continuous Improvement	A3	A	A	A	A	PA	A	A
Governance	Plus and Deltas	A	A	A	A	PA	A	A
	Agenda	A	A	A	A	PA	A	A

In the case of the **Lookahead** digital tool, the traditional format had a more satisfactory result. The first learning cycle started by using a digital Lookahead in MIRO and changed to the traditional tool after six months of Lean Implementation in Company A. A positive aspect of the digital version was the possibility of sharing the link with other construction project teams to start getting familiar with the tool before the beginning of its learning cycle. Table 2 shows that Lookahead had five to seven VM concepts partially adopted. The same could be observed regarding the **Line of balance** digital tool. Six to seven VM concepts were classified as partially or non-adopted. During the diagnosis, this tool was carried out at the MIRO and helped also with the preliminary decisions regarding the constructive sequences and the activities packages definition. The traditional format was adopted for the implementation phase due to the challenges related to the simplicity of functioning. Company A has analyzed the implementation of this tool on a Web platform, seeking to fulfill more requirements. This analysis was not the scope of this work.

Throughout the learning cycles, the importance of having the information available on the walls close to the crossing path of different hierarchical levels became evident. By fixing on the wall the traditional tools of the learning cycles phase, such as line of balance, lookahead, and check-out, collaboration and autonomy regarding planning became more spontaneous, not being restricted to routine meetings. In addition, this format was key to supporting the understanding and engagement of the operational-level employees in implementing the LPS planning levels, contributing to the adherence and spontaneous construction of a lean culture in the company. The employees gathered around them to check and discuss their daily productions and compare them with other teams, and a routine of continuous improvement between the company and partners was built. Stopping in front of a board, even for a few minutes, is strong evidence that the visual device is useful (Valente et al., 2019).

The **right amount of information available** was another VM concept with limited adoption by the digital tools. This can be related to the MIRO challenges in fulfilling the VM concept of easy information accessibility and to its limitations in data processing, seeking to develop indicators. This VM concept is related to the waste of visualization in digital environments (Murata 2018), and to the lack of directed focus, when the structure of a visualization doesn't draw attention to the issue at hand (Eppler and Bresciani, 2013). According to Pedó et al. (2020), the excess of information available can result in difficulties to find and select, i.e. prioritize the information needed and, consequently, affecting the team engagement with the tool and creating barriers to access the information. Some practices were used to reduce the effect of the overload of information, such as visual signs, use of colors and arrows, step-by-step instructions, among others. These mitigations seem appropriate for the employees that use the digital tools to support the collaborative meetings on a weekly or daily basis. However, considering the other hierarchical levels, dashboards bringing the main results and their respective impact could be incorporated into the company's routine. Dashboards could also help to increase the adoption of easy information accessibility' VM concept.

Considering dashboards analysis, it was observed that variations in indicators may suggest distinct abilities to identify restrictions and a lack of **standardization** in the conduct of the LPS methodology and tools development. The digital tools used for continuous improvement and governance had this VM concept fully adopted due to its characteristics of having their information divided into independent and non-cumulative information or work packages, such as **Agenda** and **A3**. **Plus and Deltas** was always associated with another digital tool, allowing the traceability of information.

Although the **Swimlane** was held in a traditional format, its digital version was extensively used as a basis for discussions throughout the following workshops. The information, with particular reference to the problems or improvement opportunities, was revisited along the journey in order to remember the context and purpose of the project and to compare it with the desired state. Traceability and the easy access were of great value as they helped the team to achieve directed focus on the issue at hand.

The digital tools were better suited to the strategic and tactical levels; at the operational level the tools were mostly traditional. This can be explained by the greater detailing of activities and the importance of assessing performance and control indicators at each planning level. In this sense, the limitations of MIRO led to the adoption of traditional tools at the operational level, since most of the assessed constructs were not achieved in the digital one. Furthermore, the closer to the operational level, the further into the construction site the information is. Therefore, the implementation of digital VM at the construction site presented limitations (Murata 2018) in terms of cost, equipments' safety, availability of information, internet connection, among others. Advanced practices that support production are expected to be located close to their place of use, in order to facilitate their access by the user (Tezel et al., 2009).

The main benefits from the use of digital VM tools through MIRO identified over this exploratory research can be summarized as follows: (i) allowed the collaboration during COVID-19 and between geographically decentralized teams; (ii) increased process transparency on strategy and long-term planning levels; (iii) eased communication between different hierarchical levels and between construction sites, enabling autonomy of learning; (iv) facilitated the information to be quickly delivered, organized and connected with friendly graphics, enabling the team to become more engaged and autonomous; and (v) helped to tell the implementation story as information can be recorded and presented on a single endless board with high editing flexibility. Conversely, the barriers were: (i) a fragmented flow of information between planning levels; (ii) limitations in the development and analysis of performance indicators; (iii) limitations in standardizing information, such as the use of drop-down lists or error-proofing devices that assist in building a database to be used in decision making and continuous improvement; and (iv) unavailability of information regarding long, medium and short term planning tools into the operational level and at the construction site office, restricting the spontaneous continuous improvement of the planning to the routine meetings, as the tools were not available all the time for the team to stand in front of it and collaborate.

CONCLUSIONS

This exploratory study discusses a LPS implementation held in four pilot projects during COVID-19 that had its methodology abruptly adapted from traditional to digital tools using digital and collaborative tools. The full digitization of VM tools did not suit all the phases of the LPS implementation in Company A. Visual devices that do not reach their potential in the digital environment and lack most of the requirements discussed in this paper can coexist in a traditional format with digital VM tools or in hybrid formats. The results indicate that (a) digital VM tools seemed more suitable for the strategic level of planning and for the governance of the project, as it’s shown in Table 2, considering Swimlane for Process Mapping and the Sequence Activities for Master Planning, while (b) traditional VM tools showed a better response to the tactical and operational levels, as discussed on previous sections about the Lookahead Planning on Traditional tools. In this sense, there is a challenge regarding the integration of digital and traditional tools in order to achieve automation and a better flow of information between planning levels.

The discussed tools are not meant to solve individual problems but support the implementation of a methodology for managing construction sites and improving processes. In this regard, seeking ways to integrate them and to fully adopt VM concepts discussed along this paper seems essential to reach better results. Remote collaboration, communication between hierarchical levels, and the quality of the information’ register and organization were the highlighted benefits. The main gaps that must be addressed in the digital tools were the limitations on developing and analyzing performance indicators, the challenges on standardizing information, and its negative impact on generating databases that support decision-making.

Some limitations of this exploratory study are: (i) MIRO as the only tool used throughout the LPS implementation by the consultancy company; (ii) the use of VM concepts from a design management context. The discussion of the tools in the context of building execution showed that automation and communication are central themes for a broader analysis of their implementation, discussing digital versus human-centered approaches. Future research may (i) assess the global results for the four construction sites at the end of the execution phase; (ii) investigate their relation with the constructs proposed by Pedó et al. (2020); and (iii) explore MIRO plugins and other tools, e.g. MURAL and Google Jamboard, seeking to achieve higher automation, performance indicators, information availability and standardization. Consultancy and construction companies can benefit from these discussions regarding the adoption of traditional and digital tools in a LPS implementation.

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