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BIM AS AN ENABLER OF LEAN CONSTRUCTION IN THE PUBLIC SECTOR

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ABSTRACT

Several governments are mandating Building Information Modeling (BIM) for public construction worldwide. While this top-down approach can be effective in some contexts, the lack of a lean construction perspective within BIM project delivery might hinder the expected outcomes. This paper aims to unpack the interplay between lean principles and BIM adoption that support formal and informal lean construction implementation in the design phase of public construction projects. The study focuses on a Latin American country subject to a current BIM mandate. Qualitative data was collected through semi-structured interviews with senior public sector practitioners. The findings reveal that the BIM practices *informally* align with lean principles, as there is no explicit emphasis on lean implementation within the BIM mandate framework. Drawing on these insights, the discussion compares these results with previous studies and suggests the inclusion of BIM as a facilitator of lean practices in the Lean in Public Sector (LIPS) agenda. The conclusion highlights the current opportunities for leveraging the BIM public policy trend towards lean implementation in public construction projects.

KEYWORDS

Lean construction, BIM, lean-BIM synergy, lean in the public sector (LIPS), public policy.

INTRODUCTION

Lean construction and building information modeling (BIM) have positively impacted the construction industry, and their interaction has been a major topic of discussion in both research and practice. Koskela (1992) defined lean construction as the application and adaptation of the underlying concepts and principles of the Toyota Production System (TPS) to construction. On the other hand, BIM is "a verb or adjective phrase to describe tools, processes, and technologies *facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation."* (Eastman et al., 2011).

Despite being independent efforts to transform and enhance construction as an industry, lean construction and BIM share similarities and differences in adoption and potential outcomes once implementation occurs (Sacks et al., 2010). Bhargav et al. (2013) argued that lean and BIM have four significant mechanisms of interaction: BIM contributes directly to lean goals; BIM enables lean processes and contributes indirectly to lean goals; auxiliary information systems, enabled by BIM, contribute directly and indirectly to lean goals; and lean processes facilitate the introduction of BIM. Andujar-Montoya et al. (2019) found that BIM considerably reduces construction waste in the form of lack of information exchange, poor communication, poor decision-making, and frequent design changes. Moreover, Eastman et al. (2011) stated

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that some of the principles of lean construction can be fulfilled by using BIM, and it will also enable the achievement of other principles.

Considering the interaction between lean and BIM, several studies have proposed frameworks to understand their relationship and guide their adoption. The interaction matrix of lean principles and BIM functionality presented by Sacks et al. (2010) provided examples based on published research on how lean and BIM align. Bayhan et al. (2023) also developed a framework that shows how lean and BIM interact and then validated the more relevant topics of these interactions through five case studies. Similarly, Karatas and Budak (2023) proposed a lean and BIM framework for the construction phase only, which was then validated through a statistical approach. On the other hand, other papers have presented case studies of the lean construction-BIM synergy, such as the ones presented by Khanzode et al. (2006) with Virtual Design and Construction (VDC), Rischmoller et al. (2006) with lean principles in the design stage, and Sacks et al. (2009) with the use of BIM to enhance product and process design. More recently, Eldeep et al. (2022) demonstrated using BIM as a lean tool to minimize construction waste and reduce the number of change orders in an educational project. Similarly, McHugh et al. (2019) combined the use of production planning software to implement lean tools and BIM models to improve visualization and enhance the project delivery phase of a data center. In sum, previous research has investigated BIM and lean interactions, but there seems to be a gap in how these interactions work in public construction.

Several countries have implemented BIM as a public policy to enhance public construction in their regions. Given the interaction of lean and BIM, these public policy efforts represent an opportunity to ask whether *formal* or *informal* lean construction applications can also be implemented. Unfortunately, several BIM implementation policies focus primarily on the administrative aspects of BIM project delivery (e.g. plans and documentation) without consideration of BIM-enabled production management. Consequently, this paper aims to understand the opportunities for lean implementation using BIM policies as an enabler in the public sector. To achieve this objective, this research focuses on the design stage of public projects in the Peruvian public sector, which served as the case study.

This paper is structured as follows. First, a literature review exploring the interactions of lean construction and BIM in public construction is introduced. Subsequently, the research methodology is presented, culminating in the presentation of results, including the alignment of lean principles with BIM use in the design stage. Following this, the discussion section will contrast the findings with prior research and current trends of lean construction. Finally, the conclusion section summarizes the results and proposes avenues for future research work.

LITERATURE REVIEW

LEAN CONSTRUCTION AND BIM

Sacks et al. (2010) presented one of the most acknowledged lean and BIM interaction matrices in the construction management literature. They found 56 interactions between lean and BIM, and 48 of the 56 were supported by practical evidence from industry case studies showing how BIM functionalities (or BIM uses) positively enable the achievement of lean principles. This matrix suggests that an incremental and integrated adoption of lean and BIM can enhance project and organizational results rather than their adoption separately. Oskoui et al. (2012) extended Sacks et al. (2010) interaction matrix by adding more BIM functionalities and lean principles enabled by this new set of BIM uses. These new interactions were found primarily in the operations & maintenance phase of projects.

Bayhan et al. (2023) proposed a lean and BIM framework using an analytical network process to find the most predominant factors contributing to the lean and BIM synergy. The study results showed that production, standardization, and information accuracy are the most

critical factors, and they are mainly used to control production during the delivery phase of projects. Similarly, Karatas and Budak (2023) developed a framework to understand the impact of lean and BIM synergy in labor productivity during the construction phase. That study argued that the BIM uses of 4D planning and coordination support achieving lean principles. Furthermore, using 4D models alongside visual management tools such as dashboards significantly impacts construction labor productivity.

The literature also shows many lean and BIM case studies that provide practical evidence of these synergies in various contexts. Vestermo et al. (2016) developed a project on-site hardware called "BIM station," which facilitates the integration of lean construction and BIM, considering the application of BIM solutions to satisfy lean principles, such as visual management. Gerber et al. (2010) presented three case studies on the integration of lean and BIM. All three case studies showed advancements in delivering increased value to clients while significantly reducing waste in time and material. Gomez Sanchez et al. (2019) presented the use of BIM models with lean tools and methods (i.e., lines of balance, visual management, the Last Planner System) as good practices in the Colombian construction industry. In this case, conducting a BIM implementation seems to allow for a "leaner" project as it facilitates a better communication flow to obtain more reliable production plans.

Mollasalehi et al. (2018) developed a lean BIM maturity model to assess the joint implementation of both innovations in construction. That study proposed an integrated BIM and lean maturity model called IDEAL, which adopted the initial concepts of previous BIM and lean construction maturity models. Previous research have provided an extended understanding of the lean and BIM synergy, the frameworks developed to explain it, examples of their implementation, and how to assess their joint implementation. However, most examples are from the private sector. Understanding the challenges of conducting this effort in public projects is a significant gap that this study intends to address.

LEAN CONSTRUCTION AND BIM IN THE PUBLIC SECTOR

Considering the systemic and wide approach of lean construction and its foundation in lean production, the implementation of lean construction comes along with instrumental changes in how public organizations are managed. Several authors have found significant challenges and barriers for implementing "lean" as a way of thinking and as a foundational aspect of the practices in the public sector. Bathia & Drew (2006) conducted a study to implement lean manufacturing techniques in the United Kingdom (UK) public sector, concluding that "*Applying lean is difficult in the private sector, and more so in the public sector. Therefore, successful lean transformations must close the capability gap early in the process so managers and staff can make the transition to a new way of working*."

Andersson et al. (2023) conducted quantitative research that showed some challenges in understanding what "lean" means in several Norwegian public sector workers. Based on that study, lean is perceived mostly as a set of tools instead of a way of thinking or as a mindset that can be beneficial for delivering more value to the end users of public services. This study also showed several misconceptions about lean and the lack of focus on production and flow management, which is inherent to the concept of lean as it was conceived in the 1950s. Having said that, more specific studies use public projects as case studies to showcase lean construction-related concepts, techniques, or principles (e.g. Kuprenas, 1998; Prado, 2021).

Kuprenas (1998) presented the implementation of lean thinking concepts, tools, and processes in the City of Los Angeles Bureau of Engineering due to poor project delivery performance. Kuprenas (1998) explained a holistic perspective of their lean journey, which contains organizational changes, systems optimization training, and implementation of performance metrics that combine production-related metrics and cost and time metrics. Recently, LIPS emerged as an international forum where practitioners share lessons learned

during lean transformation in the public sector and non-profit organizations (LIPS, 2024). Currently, based on the LIPS website, their research areas are Lean in Healthcare, Transformation in Transportation, Empowering people in Utilities, Lean Thinking in Education, Future of Infrastructure, and Principles of Lean Services. The specific topic of lean construction implementation in the public sector enabled by technologies such as BIM is not explicitly stated as part of the agenda items of this organization. However, one of the objectives of the 2022 LIPS conference (LIPS, 2022), which was held in Chile, was to inspire Lean initiatives in public programs, including digital technologies/BIM. Therefore, there seems to be a current discussion on integrating lean and BIM in specific projects and several public sector programs to enhance the delivery of public infrastructure.

The current implementation of BIM as a public policy in several countries (particularly in Latin America) could be used as an enabler to implement not only lean in public projects but also change the way of working in public organizations towards delivering more value to the end-users (i.e. the beneficiaries of the infrastructure delivered). Based on the BIM Network of Latin American Governments, the Latin American region intends to pursue a collaborative effort to implement BIM towards accelerating national digital transformation processes (Red BIM Gob Latam, 2024). Considering that this paper uses Peru as a case study, it is important to mention the current state of the BIM public policy in this country. The BIM adoption policies are led by Plan BIM Peru of the Ministry of Economy and Finance as the regulatory public body in charge of disseminating and overseeing this public effort (Plan BIM Peru, 2024). Several pieces of policy documentation have been published, and the ultimate goal is to use BIM for all public projects by 2030 (Ministry of Economy and Finance, 2023).

Despite the apparent positive interactions between lean and BIM, it seems that no piece of policy addresses these two innovations. However, the literature shows that some public organizations have used lean and BIM collaboratively through case studies. For instance, Umstot et al. (2014) presented a public sector case study in which BIM enabled lean construction. This case study was developed thanks to the combination of two factors: (a) the 2008 Californian law, which granted authority to community colleges to use design-build contracting to deliver capital projects exceeding $2.5M, and (b) the decision of the San Diego Community College District (SDCCD) to require all new projects to be designed and constructed using BIM. Umstot et al. (2014) demonstrated how the combination of lean construction significantly impacted change order reduction, schedule reliability, and the completion of sustainability certification. In the case study of that research, the use of BIM allowed the project to achieve several lean principles.

Monyane et al. (2018) included BIM as a lean construction tool to enhance the cost management framework in South African public sector projects. In that study, Monyane et al. (2018) conducted interviews and found that many respondents agreed on the use of BIM to enhance design and construction workflow and the application of BIM uses (i.e., clash detection) to improve design documents. Similarly, Prado (2021) discussed the use of BIM and lean in combination with the Virtual Design and Construction (VDC) implementation process (and its challenges) in Peruvian public projects. Moreover, Prado (2021) stated that the need for a lean approach is instrumental to overcoming several challenges in implementing these innovations.

Given the influential role of the government in the industry, its ability to encourage and empower public organizations is crucial for delivering value throughout the project lifecycle. These studies indicate that integrating lean construction tools, methods, and innovative technologies can enhance performance in public construction projects. Therefore, the application of a framework that integrates these two concepts, such as the lean and BIM framework presented by Sacks et al. (2010), could be used as the theoretical artifact to understand the opportunities for joint implementation of lean construction and BIM.

RESEARCH METHOD

Given the background of the authors of this paper with the Peruvian public construction sector, and the similar approach in BIM implementation in the Latin American region, Peru was selected as the case study. The first step is to develop a version of the lean and BIM interactions framework. Considering the context of the BIM implementation policies in Latin American countries and the lean and BIM interaction matrix presented by Sacks et al. (2010), this study proposes a more specific version of this framework addressing the design phase. The second step is to develop a qualitative analysis process based on semi-structured interviews with public managers. These public managers are required to have experience in managing public projects implementing BIM and have knowledge of lean construction, so the interactions between these two innovations can be found through the interviews. The interviewees were asked questions about the interaction of lean and BIM in the projects they manage and how lean principles are enabled using BIM. The questions were:

- How many projects have you developed with BIM?
- What do you understand as lean construction and lean overall?
- Based on the list of lean principles, which lean principles are enabled by each BIM use implemented in your projects? Could you elaborate on the evidence?

The demographics of the managers are shown in Table 1.

Table 1: Demographics of public managers interviewed

N°	Public organization	# of years of experience	# of projects using BIM
1	Ministry of Housing	20	10
2	Ministry of Education	15	8
3	Ministry of Education	5	5
4	Ministry of Housing	23	20
5	Regional Government of Callao	30	4
6	Ministry of Education	16	9
7	Ministry of Economy	30	25

The third step is to find the similarities and differences in the lean principles (including lean tools and methods) that BIM enables based on the experiences shared by the interviewees. Using the answers of all the interviewees facilitates the construction of a more robust understanding of the perception of public managers regarding how BIM (uses) supports the satisfaction of lean principles and the evidence related to it. This step will lead to obtaining an explanation of how lean principles are enabled by BIM in the public sector.

RESULTS

CASE STUDY CONTEXT

Projects developed under the Peruvian public construction legislation follow a typical design-bid-build (DBB) as the delivery method of choice (Ministry of Economy and Finance, 2018), which mainly focuses on financial accountability, and generates fragmentation among project stages. Additionally, public projects usually involve many actors throughout their phases, and the regulatory body auditing public procurement constrains public managers from innovating if there is no specific piece of legislation that supports that innovation. Consequently, managing

public projects is considered a heavily bureaucratic process, and innovation is usually triggered after a policy is released to "shield" public managers who decide to implement it. In this regard, a new BIM policy now allows public institutions to implement BIM uses and conduct BIM implementation (at organizational and project levels). This policy is also included in different types of delivery methods not commonly used in this sector, such as design-build, and legal frameworks that differ from the standard used in the case study, such as the New Engineering Contract (NEC). Considering the interrelated relationship between lean and BIM and the current BIM policy, the case study context has many variables to study that might or might not affect the opportunities for lean principles to be included in the current BIM mandate.

LEAN CONSTRUCTION & BIM INTERACTIONS IN THE DESIGN STAGE

Table 2 shows the outcome of the lean and BIM interactions in the case study. This is shown by aligning lean principles to BIM functionality based on the case study.

Table 2: Lean construction & BIM framework in the design stage of public projects

BIM functionalities (BIM uses)	Lean Principles (validated by the case study)
Visualization of form (Existing conditions records, 3D visualization)	Reduce variability Verify and validate Go and see for yourself Use visual management Ensure requirements flow down
Rapid generation of multiple design alternatives (Design authoring, Design review, 3D Model coordination)	Reduce variability Reduce cycle times Use visual management
Automated generation of drawings and documents (Documentation production, Quantity take-off)	Reduce variability Reduce batch sizes
Collaboration in design and construction (3D Model coordination, 4D Model simulation, Data coordination, 3D Visualization)	Reduce variability Reduce cycle times Increase flexibility Ensure comprehensive requirements capture Verify and validate Decide by consensus considering all options

In the first column of Table 2, the BIM functionalities are drawn from the initial lean construction and BIM interaction matrix, and the associated BIM uses (in parenthesis) are drawn from Plan BIM Peru. This portion of Table 2 shows the “correlation” between the BIM functionality and BIM uses extracted from the two pieces of literature used in this study. This alignment was necessary to ensure a good understanding of terminology during the interviews with the public managers. Moreover, Plan BIM Peru is working on having the same language within the public sector in terms of the terminology used for BIM-related concepts. The lean principles are presented with the same terms as the original interaction matrix. The explanation of these terms was also part of some interviews with the public managers who participated in this research.

The results of Table 2 show that the BIM functionality of Collaboration in design and construction (the combination of the following BIM uses: 3D Model coordination, 4D Model simulation, Data coordination, and 3D visualization) enables more lean principles than the other

BIM functionality for the design phase of projects. This BIM functionality enables six lean principles based on the interviewees' responses. These lean principles are: reduce variability, reduce cycle times, increase flexibility, ensure comprehensive requirements capture, verify and validate, and decide by consensus considering all options. The BIM functionality of visualization of form (the combination of the following BIM uses: Existing conditions records and 3D visualization) enables five lean principles: reduce variability, verify and validate, go and see for yourself, use visual management, and ensure requirements flow down.

The BIM functionality of Rapid generation of multiple design alternatives (combining the following BIM uses: Design authoring, Design review, and 3D Model coordination) enables four lean principles: reduce variability, reduce cycle times, and use visual management. Lastly, the BIM functionality of Automated generation of drawings and documents (combining the following BIM uses: Documentation production and Quantity take-off) enables two lean principles: reduce variability and batch sizes. From a BIM perspective, there are overlaps in the BIM functionality's impact on lean principles (several BIM functionalities impact several lean principles), which shows the complex and multilayered interaction between lean and BIM. Additionally, it seems that the BIM uses combined could also provide more robust support to a combination of lean principles.

LEAN PRINCIPLES ENABLED BY BIM

The results of Table 2 present the relationship between lean and BIM in the public construction sector, specifically in the design phase of the case study. From a lean construction perspective, the BIM functionalities analyzed enable eight lean principles. To facilitate the explanation of the interrelated connections among some of the lean principles and the BIM uses that enable them, some lean principles are going to be presented paired.

Reduce Variability

All BIM uses enable this lean principle, and the public managers believe that *"BIM allows building two times the project, and as a consequence, less waste (fewer sources of variability) will happen when the projects are constructed."* Some of the public managers most knowledgeable in lean construction mentioned that combining early 4D-BIM modeling with lean tools and methods (i.e., target value design and value stream mapping) might allow for reducing even more sources of variability in the early stages of the projects. Furthermore, there is evidence of conducting training programs in specific lean tools and methods, being The Last Planner System the most common one among the training programs in the public sector. Additionally, the contracting methods currently employed in public projects provide greater flexibility for conducting operations management studies and gathering data on the impact of variability, thereby facilitating efforts to mitigate these sources of variability.

Go and see for yourself & Verify and Validate

All the interviewees mentioned their practices of engaging with the team members and seeing the "sources of waste" as part of their duties, as well as how BIM models support this activity by providing a "virtual *gemba* walk." These activities are now considered a collaboration section in the BIM policies, expecting to enable more positive interactions among stakeholders. These lean principles are also validated and improved through BIM by authoring and reviewing design models in the early stages of the project, which enables to understand better future issues and ways to mitigate them. Additionally, these lean principles insert transparency during the project's design phase, and transparency is a major value in public construction. This principle of BIM is a significant cornerstone of the current BIM mandate.

Use Visual Management

The use of BIM models and outcomes of the BIM uses for reporting, and dashboard development in design seems to be the most common interpretation of how BIM enables this lean principle. Obtaining data to feed the project's visuals since the early stages is a current initiative that most public managers are conducting. Additionally, some public managers mentioned including BIM models and BIM deliverables to develop A3 reports, which shows a combination of lean tools and methods supported by BIM uses. They mentioned they learned these lean tools and methods from different sources, which include institutional training. Moreover, the use of 4D BIM models to develop on-time interaction dashboards and evaluate several design options from a constructability perspective were other examples collected through the interviews conducted.

Reduce cycle time

The combination of having different templates to apply BIM uses provided by public clients and process maps for lean tools and methods makes it seem that BIM allows the reduction of cycle times of several pieces of the design scope supported by BIM. This cycle time reduction mainly happens with design documentation production because it facilitates an almost automated documentation standard in each public institution and a standard process for reviewing procedures and submittals within the private sector institutions. However, there was no emphasis on how reducing cycle time is related to production systems optimization when the interviews were conducted. Additionally, it seems that there is no understanding or acknowledgment of production systems, or production management applications in projects, which are foundational concepts in the lean construction body of knowledge.

Decide by consensus considering all options

Public managers pointed out that designers use BIM models to evaluate different alternatives, reducing potential changes because of the previous visualization of potential issues and helping to incur in a set-based design approach. In this regard, the owner's involvement in the project comes with collaborative efforts from both parties, which is stated in the BIM policy. However, the public managers seem reluctant to understand how this collaborative effort might work, considering the current problems related to corruption allegations in public projects. This is a major root cause of the high levels of bureaucracy and poorly managed accountability of public projects.

Ensure comprehensive requirements capture & Ensure requirements flow down

These two lean principles are related as they intend to keep the value throughout the whole delivery phase of the project, considering building standards and end-user requirements, and properly translating these needs into technical decisions. For this reason, implementation of BIM uses such as design review, visualization, and automation through BIM models allows to keep track of the value and benefits of the project to their users and beneficiaries. These BIM uses allow for the overseeing of any potential building standard infraction and the keeping of the "value" intended for the project by visualizing and analyzing the early design during the design review process with BIM models. Furthermore, one of the interviewees mentioned that in one police department project, the designers were able to show the final product to the police officers (beneficiaries) to use the building, and they were able to discuss project decisions thanks to the BIM models. This example highlights how BIM allows to maintain value by facilitating the interaction with the other stakeholders (primarily the ones not related to construction-related disciplines).

DISCUSSION

The findings of this research seek to understand the opportunities for lean construction implementation (*formally* or *informally*) by enabling lean principles within the context of BIM implementation policies. While the findings of this study show several opportunities for lean construction implementation in public projects, some concepts related to lean construction were required to be explained while conducting the interviews with the public managers. This study also did not ask for specific tools and methods (such as the Last Planner System or Target Value Design), but rather for the lean principles embedded in the lean tools and methods. The public manager's misconception of the relationship between lean construction and production management represents a challenge to the application of lean in the public sector. Furthermore, the concept of value in projects, along with its various implications, appears to be complex and is subject to varying interpretations by public managers. Lujan & Murguia (2022) also discussed this concept and how the Lean Project Delivery System can facilitate the definition of value in public projects.

In terms of the BIM uses or BIM functionality, the interviewees showed some confusion with the specifics and implications of each BIM use, such as the digital deliverable required to complete the application of each BIM use. The interviews were facilitated by providing different names for each BIM use depending on the literature used by the public managers. Regardless, the BIM uses table developed by Plan BIM Peru is supposed to be used as the standard for this type of effort. The BIM Dictionary developed by the BIM Excellence Initiative (BIM Dictionary, 2024) is expected to clarify this concern and have only one source, if possible, to obtain BIM-related definitions. This research needed to "cluster" BIM uses to match the BIM functionality stated in the original lean and BIM interaction matrix. Furthermore, obtaining a more granular table between the interaction of lean construction and BIM uses (not BIM functionality) might provide different results from the ones obtained in Table 2.

Previous studies on the interactions between lean construction and BIM for specific principles and functionalities have not used case studies in developing countries. This study shows empirical results on how these relationships emerge in public construction projects. However, since the authors used the preestablished lean principles associated with the BIM functionality in the design phase of projects, there might be more lean principles enabled by the same BIM functionality. Considering a different lean construction and BIM interaction framework, such as the ones proposed by Karatas & Budak (2023), can also provide a different perspective on the implications of lean construction and BIM implementation altogether in public projects.

These results also provide a broader perspective of two significant opportunities. First, the option of enabling lean principles as part of the BIM mandate, considering the benefits of implementing these two construction paradigms together. This can also be useful in setting a new trend in the Latin American region towards an improved construction sector as eight countries follow a similar BIM implementation journey. Second, considering an even broader perspective, LIPS can also include more case studies of the enablement of lean construction in public projects (and public organizations in general) as it represents a very challenging topic to implement lean towards a more holistic approach. This second opportunity is also related to other efforts trying to implement lean-related concepts (not only within the construction industry). An example of these efforts was presented by Bathia & Drew (2006), Monyane et al. (2018), and Andersson et al. (2020) in the literature review section of this paper.

By adding lean principles to the current BIM mandate for public projects, benefits will arise as the interaction of lean construction and BIM are virtuous, and these two innovations support each other. Moreover, this research presented a baseline to understand better the interaction of lean and BIM from a developing country perspective.

CONCLUSIONS

This research aimed to understand the opportunities for lean implementation using BIM as an enabler in the public sector. To achieve this objective, this study focused on the lean construction and BIM interactions presented in the Sacks et al. (2010) interaction matrix to construct a more specific framework, which was then used to interview public managers of the Peruvian public construction sector and validate the enablement of lean principles. The findings show that the implementation of BIM enables eight lean principles uses: reduce variability, go and see for yourself, verify and validate, use visual management, reduce cycle time, decide by consensus considering all options, ensure comprehensive requirements capture, and ensure requirements flow down. Although these lean principles seem to appear "informally" during the delivery of public projects, more practical applications of lean were also pointed out in the case study, such as The Last Planner System, value stream mapping, set-based design, A3 reports, and other lean tools and methods being used in public projects.

This study has some limitations including the project phase under examination and the unique context of the Peruvian public sector. Future studies could conduct in-depth case studies to reveal more insights into the body of knowledge of how lean construction and BIM interact. Moreover, this study reveals new perspectives of a more integrative umbrella for implementing digitalization and production management in construction, which are being exposed in the construction industry through BIM and lean construction, respectively. Therefore, conducting future research considering these wider perspectives could be beneficial to understanding a more integral improvement process of the construction industry.

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