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ANALYSIS OF VDC PERFORMANCE AND ITS INTERACTION WITH LEAN CONSTRUCTION IN PERU

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ABSTRACT

The present study aims to analyze the performance of Virtual Design and Construction (VDC) in construction projects in Peru, evaluating its interaction with Lean Construction. Through a systematic approach, it seeks to identify how these tools contribute to the success of projects, improving efficiency, collaboration and sustainability in the construction industry. The research uses a methodology based on data collection through surveys and review of case studies. This will allow obtaining a comprehensive view of the main challenges and benefits associated with the implementation of VDC and Lean Construction (LC) in the Peruvian context. It was identified that the benefits associated with the integration of VDC and LC are consistent with the existing literature, validating its ability to generate value, reduce waste and facilitate collaborative decision making. In addition, the role of Lean tools, such as the Last Planner System, in the consolidation of planning and control strategies was highlighted. This work contributes to reinforce the practical knowledge on the application of VDC in construction projects in Peru, providing professionals in the industry with insights into best practices, challenges, and strategies to optimize implementation.

KEYWORDS

Lean construction, VDC, Virtual Design, Construction, Implementation.

INTRODUCTION

Construction is one of the sectors with the greatest economic impact worldwide, contributing 13% of global Gross Domestic Product (GDP) (Del Savio et al., 2022). Labor productivity growth in this sector has been limited, with an annual increase of only 1% between 1995 and 2014, resulting in lower quality products, lead time inefficiencies, and higher production costs (Quiso et al., 2021). The architecture, engineering and construction (AEC) industry considered one of the most resistant to change (Mandujano et al., 2016), faces challenges derived from factors such as contracting systems, interorganizational relationships, and lack of adequate organizational resources (Del Savio et al., 2022). These limitations generate delays, cost overruns and mistrust among stakeholders (Prado, 2021). In response to these challenges, the construction industry adopts new forms of project management, being Virtual Design and

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Construction (VDC) an emerging methodology that together with Lean Construction (LC), is a key alternative to improve the efficiency and results of projects (Rodriguez et al., 2021).

VDC and LC have emerged in the last decade, consolidating themselves as key approaches to optimize process efficiency in construction (Aslam et al., 2021). Mandujano et al. (2016), defines VDC as 'the use of integrated multidisciplinary performance models of design-build projects to support explicit and public business objectives'. This approach enables more efficient production planning by eliminating design conflicts in the virtual environment before they materialize in the real world (Maraqa et al., 2021). In addition, Lean Construction focuses on understanding value from the customer's perspective, minimizing non-value adding waste, increasing process stability and transparency, optimizing flow with a pull system, and fostering a culture of continuous improvement (Fosse et al., 2017).

The benefits of these tools have been demonstrated in international projects, such as Cathedral Hill Hospital in the United States, where a reduction of repetitive work was evidenced (Hickethier et al., 2012) and the University of California at Santa Cruz, where a time saving of 70% was reported (Choo & Fischer, 2010), and in projects in Peru as in the laboratories of the University of Lima where the duration of processes in operation and maintenance was reduced (Bazán Montalto et al., 2024), however, implementation challenges are still faced. Among the main difficulties is the acceptance and adoption by stakeholders (Bakhoum et al., 2023). According to a survey conducted by Bazán Montalto et al. (2024), although 73% of the participants accepted the methodology, 27% still presented resistance, affecting interdisciplinary collaboration and optimized workflow. On the other hand, the success of VDC also depends on having complete and accurate data available at critical stages of the project Merino Chocano et al. (2024) identified that only 72% of the necessary information was available at key moments, compromising planning and delivery times. These challenges show that effective implementation of VDC requires a deep and structured understanding of how its principles operate throughout the different stages of a project.

In this sense, LC emerges as a necessary foundation to facilitate the adoption of VDC (Alarcon et al., 2013). Lean not only allows optimizing processes and reducing waste but also provides a solid framework to understand and apply VDC principles more efficiently (Del Savio et al., 2022). The main objective of this study is to analyze the performance of the VDC methodology in Peru, exploring its interaction with LC principles. Through this analysis, it seeks to identify not only challenges and challenges, but also opportunities for improvement for its implementation. The document is structured in five main sections: the present introduction, a literature review, the methodology used for the research, the results obtained - which include relevant quantitative and qualitative findings- and the conclusions.

LITERATURE REVIEW

LEAN CONSTRUCTION

Lean Construction is a management philosophy aimed at eliminating waste and optimizing the processes of design, supply, and construction through a project-based production system (Aslam et al., 2021). Its implementation focuses on generating value for the client, fostering continuous improvement, and encouraging collaboration among all project stakeholders, which contributes to more efficient and coordinated project execution. According to Maraqa et al.(2021), this approach prioritizes the optimization of workflow and effective task coordination through specific tools such as the Last Planner System (LPS), which enhances communication and decision-making within multidisciplinary teams.

Furthermore, Lean Construction relies on performance models that integrate various disciplines in planning and execution, reducing uncertainty and improving transparency throughout the project (Correa, 2020). Tools like the LPS ensure that planned activities are feasible and aligned with available resources, thereby increasing schedule reliability (Aslam et al., 2021). These authors also highlight that the success of Lean Construction depends on its integration with digital technologies such as VDC, as they facilitate visualization, information flow, and the integration of design and construction (Aslam et al., 2021). Studies such as (Barcena et al., 2023) highlight the optimization of time in construction processes through the application of these tools, achieving reductions in costs and time.

VIRTUAL DESIGN CONSTRUCTION

VDC is defined as the use of multidisciplinary performance models integrated into design-build projects to support explicit business objectives (Maraqa et al., 2021), The multidisciplinary model involves digital collaboration between different construction industry specialists to improve project coordination and efficiency. This methodology relies heavily on Building Information Modeling (BIM), Product and Production Management (PPM), and collaborative sessions such as Integrated Concurrent Engineering (ICE).

VDC enables early-stage integration of project data and stakeholders, allowing for proactive decision-making, reduction of uncertainty, and better risk management (Fischer & Kunz, 2004). Ocas & Merma Gallardo (2023) emphasize its role in facilitating collaboration by providing a unified framework that connects systems, data, and people. Additionally, studies like Rischmoller et al. (2018) have shown how VDC improves conflict resolution through simulation and visualization tools prior to execution.

Recent research (Merino Chocano et al., 2024; Rios, 2023) has documented significant time and cost savings in infrastructure and multifamily housing projects due to the use of VDC. Bazán Montalto et al. (2024) further demonstrate that when VDC is combined with Lean Construction and Facility Management, it leads to increased efficiency and sustainability. In Peru, Rios (2023) and Ocas & Merma Gallardo (2023) report successful applications of VDC in improving design coordination and accuracy in both architectural and infrastructure contexts.

METHODOLOGY

To analyze the interaction between LC and VDC in the construction industry, this study followed a structured systematic approach consisting of three stages: (1) Systematic Literature Review (SLR) using PRISMA, (2) Classification in evaluation topics and (3) Survey of professionals in the construction sector. The findings from both the SLR and the survey were integrated to cross-analyze theoretical perspectives with real-world applications.

APPLICATION OF THE PRISMA

The Preferred Reporting Items for Systematic Literature Review (PRISMA) methodology was used to perform a systematic review that guaranteed a rigorous and transparent selection of the relevant literature, as it has been used in several LC-related investigations ((Erazo-Rondinel et al., 2023). In the initial identification phase, six keywords were used for the search, generating 10 combinations: combinations I to VII were applied to the SCOPUS database, while combinations VIII to X were performed in the IGLC database. These sources were selected for their high degree of involvement with LC. (Galaz-Delgado et al., 2021).

The process yielded 283 preliminary results. After eliminating 93 duplicate publications, the titles and abstracts of the remaining articles were reviewed, excluding 135 that did not address the objective of VDC implementation. In a final exclusion phase, the papers were subjected to a complete reading, discarding 27 additional articles that did not meet the established selection criteria. These criteria included: (1) that the articles should address the implementation of VDC and Lean Construction in construction projects; (2) that only those works presenting empirical data or case analyses should be considered; and (3) that articles not providing a clear evaluation of the benefits or challenges of integrating VDC and Lean should be excluded. Ultimately, a total of 102 articles were selected that met these requirements and were considered in this research. This process is detailed in Figure 1.

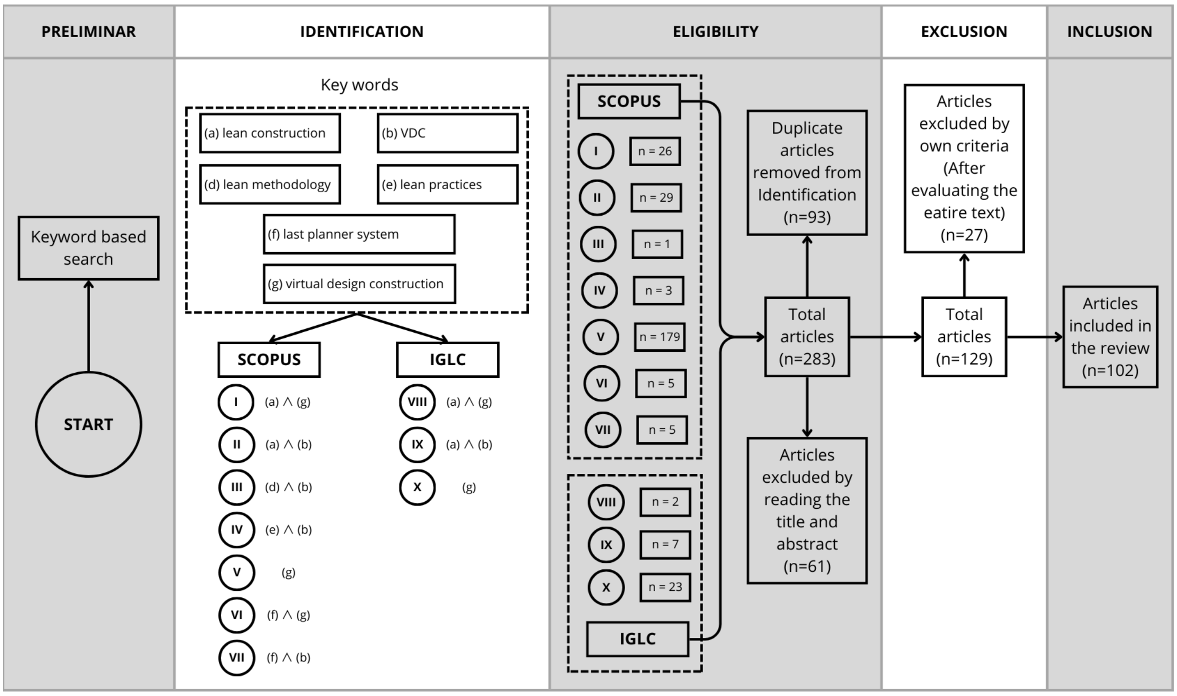

Figure 1: PRISMA methodology application flow.

CLASSIFICATION IN EVALUATION TOPICS

At this stage, the 102 selected articles were classified into specific topics in order to structure and delimit the analysis. The classification categories were defined based on the predominant approaches in the literature and their relevance to the objectives of this research. These themes include: VDC & LC Implementation, Challenges and benefits, VDC synergy with LC, LC Tools or Processes, and Case studies in Peru, as shown in Table 1.

Table 1: Thematic Classification of Research

	Classification Topics	Scope
I	VDC & LC implementation	Evaluation of strategies, stages and case studies in the implementation of VDC in projects.
II	Challenges and Benefits	Identification of factors that hinder or enhance the use of VDC in different contexts.
III	VDC synergy with LC	Analysis of how the Lean philosophy complements and enhances VDC results.
IV	Tools or Processes of LC	Tools such as A3 Reports, Pull Planning, Last Planner System, and its integration with VDC.
V	Case Studies in Peru	Evaluation of projects to analyze VDC and LC implementation, highlighting their performance and results.

SURVEY OF PROFESSIONALS

In this phase, a questionnaire was designed for professionals in the construction sector in Peru, with the objective of gathering information on the perception, use and experience related to VDC and LC. The questionnaire was structured in sections, starting with a brief explanatory introduction on both concepts, to ensure that all respondents understood the terms, regardless of their level of previous experience. A total of 100 industry professionals were contacted, with a response rate of 69%. The sample size was determined based on feasibility constraints and the need to obtain a specialized, high-quality dataset rather than a large, generalist one. Given the relatively limited pool of professionals with direct experience in VDC and LC in Peru, this number was considered appropriate to ensure meaningful insights while maintaining data reliability. Participants were selected through a purposive sampling strategy, focusing on professionals with direct project experience in VDC and LC or formal training in these methodologies. To ensure a balanced perspective, the sample included both senior professionals and early-career practitioners, capturing insights from different experience levels and project scopes. Respondents represented a range of experience levels, with some having less than five years in the industry. However, their inclusion was justified by their completion of VDC certification programs, such as those offered by the University of Lima and the Stanford Engineering Center for Global & Online Education. This selection ensures that the study captures perspectives from both experienced professionals and emerging practitioners, providing a comprehensive view of VDC adoption challenges in the Peruvian construction sector. The questionnaire employed a structured method, covering key sections related to VDC and LC. Questions were designed to address different aspects of these methodologies, ensuring a comprehensive understanding of their application in the Peruvian construction sector. The survey link (https://forms.gle/kdoyRBmBa8zV7VKt5) provides direct proof of the questionnaire's structure and content. To assess the validity and reliability of the questions, the questionnaire was reviewed and approved by a professional with prior experience in VDC certification programs, ensuring that the questions were relevant, clear, and aligned with recognized VDC frameworks.

RESULTS AND DISCUSSION

The survey was answered by professionals with experience ranging from 1 year to more than 20 years in the construction sector. Participants were selected for their involvement with the VDC methodology according to your Linkedln profile, including professionals who have participated in VDC Programs. The questionnaire began by collecting information about their years of professional experience, the types of projects in which they have participated and the stages in which this methodology was implemented. Subsequently, the questions were organized according to the five classification themes established in this research. Of the respondents, 28 professionals have between 1 and 5 years of experience, 18 have between 6 and 10 years, 10 have between 11 and 15 years, 8 have between 16 and 20 years and 5 have more than 20 years of professional experience.

VDC & LC IMPLEMENTATION

The question "What challenges did you encounter during the implementation of VDC and LC in your projects?" was included, in which respondents mentioned the most recurrent challenges as resistance to organizational change, especially in teams with extensive experience in traditional methods, and limited support from management, given that implementation requires investment of time, resources and committed leadership. In addition, lack of adequate training and limited experience with key tools complicate their practical application, leading to errors and negative perceptions. High staff turnover is another major challenge, since it complicates the picture as the knowledge acquired by the team that initiated the implementation is lost. On the other hand, the underestimation of the importance of aligning objectives from the beginning, together with communication problems and technological and budgetary limitations, hinder coordination, decision making and the overall success of the methodology.

Then they were asked about the "Lessons learned about VDC and LC implementation?", facing these challenges, the respondents highlighted that continuous training of the team is key to reduce resistance to change and strengthen its implementation. They mentioned the need to introduce VDC gradually, adapt the methodology to the context of the project and align the client's objectives from the beginning with clear metrics and well-defined plans. In addition, they highlighted the importance of assigning the VDC implementer a leadership position close to senior management, ensuring efficient ICE sessions and establishing clear roles and workflows. Genuine team commitment and the combination of Lean tools, such the Last Planner System (LPS), were identified as factors that significantly boost results, optimize processes and improve performance.

CHALLENGES AND BENEFITS

By identifying the adoption and effectiveness of VDC and LC implementation in the literature review, the main challenges are presented in Table 2 and the main benefits in Table 3.

Table 2: VDC & LC Implementation Challenges

Code	Challenges	Citations
R1	Resistance to change on the part of project stakeholders due to preference for traditional methods	(Bakhoum et al., 2023); (Barcena et al., 2023); (Li et al., 2009); (Ocas & Merma Gallardo, 2023); (Rios, 2023)
R2	Requirement to train the project team in new technologies and collaborative methodologies	(Barcena et al., 2023); (Correa, 2020); (Ocas & Merma Gallardo, 2023); (Rios, 2023)
R3	High initial cost associated with the implementation of the technological tools necessary to support the VDC methodology	(Bakhoum et al., 2023); (Said & Reginato, 2018); (Li et al., 2009)
R4	Promotion and dissemination of the VDC methodology is insufficient	(Ying et al., 2023)
R5	Project delivery methods that preclude builder collaboration from early project stages	(Said & Reginato, 2018); (Fajardo et al., 2019); (Prado, 2021)
R6	Lack of clarity in the definition of the scope by the client	(Said & Reginato, 2018)
R7	Complexity of implementation in industrial or long-term projects, where the dissemination of the methodology is more complex	Survey

All practitioners surveyed agreed that the first six challenges (R1-R6) represent key obstacles to effective VDC implementation. Stakeholder resistance to change (R1) was identified as one of the main challenges, especially in environments where traditional methods prevail. Participants also highlighted the need to train the project team in new technologies and collaborative methodologies (R2), recognizing that lack of training limits the adoption of digital tools and integrated processes. Another widely recognized challenge was the high initial cost of implementation (R3), related to the acquisition of software, hardware and specialized training. Insufficient promotion and dissemination of the VDC methodology was also highlighted (R4), which hinders its understanding and acceptance in the sector. In addition, respondents agreed that project delivery methods, which limit the builder's early involvement, represent a barrier (R5), as does the lack of clarity in the definition of scope by the client (R6), which complicates proper project planning and execution. As an additional contribution, the participants proposed a new challenge (R7): the complexity of implementation in industrial or long-term projects, where the dissemination and application of VDC becomes more difficult due to the magnitude and complexity of these works.

Table 3: VDC & LC Implementation Benefits

Code	Benefits	Citations
B1	Improves the efficient and agile exchange of clear, objective and transparent information among project participants.	(Jiménez Rodríguez et al., 2022); (Li et al., 2009); (Merino Chocano et al., 2024); (Rios, 2023)
B2	Promotes a collaborative environment of integrated decision making aligned with client and project objectives	(Ruesta et al., 2023); (Barcena et al., 2023); (Jiménez Rodríguez et al., 2022); (Gordon et al., 2022); (Merino Chocano et al., 2024); (Ocas & Merma Gallardo, 2023)
B3	Facilitate understanding of project scope by providing a visual and detailed representation of project objectives, deliverables and requirements	(Correa, 2020); (Laine et al., 2014); (Ocas & Merma Gallardo, 2023)
B4	Reduces rework by identifying and resolving problems at an early stage	(Hickethier et al., 2012); (Maraqa et al., 2021)
B5	Reduces lead times by focusing on optimization from the pre-construction phase	(Barcena et al., 2023); (Bakhoum et al., 2023); (Ruesta et al., 2023); (Choo & Fischer, 2010); (Fosse et al., 2017)
B6	Improved efficiency in project management	(Lee et al., 2022); (Ying et al., 2023)
B7	Allows to establish clear objectives for both the client and the project, ensuring an aligned vision from the beginning	(Bakhoum et al., 2023); (Fosse et al., 2017)
B8	Allows to offer different design alternatives to the client, allowing to explore options that better fit their needs and expectations	(Li et al., 2009); (Wong et al., 2009); (Ying et al., 2023)
B9	Allows to reduce the project's target budget and generate cost savings by reducing waste and improving overall project efficiency	(Adel et al., 2022); (Bakhoum et al., 2023); (Chiu et al., 2011); (Maraqa et al., 2021)
B10	Facilitates risk mitigation by identifying potential problems early and providing proactive solutions	(Adel et al., 2022)
B11	Reduces variability in project production processes, resulting in a more consistent and predictable plan-completion rate	(Fosse et al., 2017); (Murphy et al., 2018); (Quiso et al., 2021)
B12	Improved communication between design and construction teams from the early stages of the project	(Ma et al., 2018)
B13	Increases automation and prefabrication, which improves component production efficiency, reduces on-site assembly time and minimizes errors	(Staub-French & Khanzode, 2007)

All participants supported the benefits identified in the bibliography. One of the most highlighted benefits was the improvement in the efficient and agile exchange of clear, objective and transparent information among project participants (B1), which facilitates coordination and avoids communication errors. In addition, they highlighted how VDC promotes a collaborative environment for integrated decision making, aligned with client and project objectives (B2), thus improving management consistency. VDC's ability to facilitate understanding of project scope through detailed visual representations (B3) was another widely valued benefit, as it contributes to the correct interpretation of project objectives and requirements. The professionals also recognized the effectiveness of VDC in reducing rework by detecting and resolving problems early (B4), as well as reducing execution times by optimizing processes from the preconstruction phase (B5). Another key benefit was improved efficiency in project management (B6), resulting in smoother and more controlled execution. The ability to set clear objectives for the client and the project (B7) and to offer different design alternatives adapted to the client's needs (B8) were also valued as strategic advantages.

In terms of costs, participants highlighted that VDC allows reducing the project's target budget and generating savings by minimizing waste and optimizing resources (B9). They also stressed that VDC facilitates risk mitigation by identifying potential problems early (B10) and reduces variability in production processes, contributing to a more consistent and predictable workflow (B11). Finally, it was recognized that VDC improves communication between design and construction teams from early stages (B12) and promotes automation and prefabrication, optimizing production and reducing assembly times (B13).

VDC SYNERGY WITH LC

84.06% of the respondents have a high knowledge of LC and 76.81% mentioned that Lean provides a solid foundation for adopting VDC, mainly because of its focus on continuous improvement, interdisciplinary collaboration and process optimization. In addition, respondents highlighted that the application of Lean allowed identifying constraints, aligning objectives among stakeholders and promoting effective communication at all stages of the project, critical factors for the success of VDC. The implementation of regular meetings, continuous training and early integration of design and construction teams were key strategies to achieve this synergy. However, some participants noted that while Lean is not a prerequisite, knowing and applying its principles significantly facilitates the adoption of VDC, especially in the management of production processes and collaborative decision making. Additionally, the sections on VDC & LC Implementation, VDC Synergy with LC, and Tools or Processes of LC present results directly obtained from the survey. In contrast, the sections on Challenges and Benefits and Case Studies in Peru integrate findings from the literature and compare them with survey responses.

TOOLS OR PROCESSES OF LC

The question “What Lean tools have you applied in construction projects?” was also included, with the objective of identifying the most commonly used Lean methodologies in the sector. In total, 69 responses were obtained, of which 3 were not considered due to inconsistencies (contradictory, illogical, or unreliable responses) or incomplete data, leaving a total of 66 valid responses for analysis. The results allow us to visualize the frequency of application of various Lean tools in construction projects, providing a clear perspective on the most common practices in the sector. The Last Planner System (LPS) was reported as the most used tool, with a frequency of 90.9% (60 of 66). Pull Planning was next, with 66.7% (44 of 66). Balance Charts reached 37.9% (25 of 66), while Value Stream Mapping (VSM) and 5S shared a frequency of 34.8% (23 of 66). In contrast, tools such as Poka Yoke and Target Value Delivery (TVD) registered a frequency of 3.0% (2 of 66). Other methodologies, including Single-Minute Exchange of Die (SMED), Lean Training Games, Set-based Design (SBD), Choosing By Advantages (CBA), S-Curve, and A3, had a frequency of 1.5% (1 of 66).

A second question was then included: “How do you think these Lean Construction tools or processes facilitated the application of VDC? In total, 69 responses were obtained, of which, after a review process that discarded those with inconsistencies or incomplete data, 60 were validated (checked and confirmed to be complete, accurate, and reliable for analysis). The validated responses allowed us to identify several key areas that contributed to facilitate such analysis. Planning and control was identified by 20.0% (12 of 60) of respondents as a key factor in VDC implementation. Risk management and control was highlighted by 18.3% (11 of 60), while an equal percentage, 18.3%, pointed to both the implementation of tools and methods and process optimization as important enablers. Cultural and philosophical change was mentioned by 10.0% (6 of 60) of the participants, and 8.3% (5 of 60) highlighted collaboration and coordination as a relevant aspect. Finally, 6.7% (4 of 60) identified alignment and continuous improvement as a contributing factor to the VDC implementation process.

CASE STUDIES IN PERU

Thirty-three cases of VDC and LC implementation were identified, of which 6 correspond to projects executed in Peru and 27 to international projects. Internationally, Lean and VDC have also demonstrated significant improvements. In the U.S., a study on 11 construction projects using VDC found that Lean-based planning contributed to lower cost increases in intervention groups compared to control groups, (Gordon et al., 2022). In Israel, the integration of Lean tools, with BIM improved workflow continuity, reduced work interference, and minimized out-of-sequence tasks in high-rise residential projects (Maraqa et al., 2021). In the case of Peru, projects such as the laboratories at the University of Lima stand out, where early implementation of an integrated facility management system (IFMS) reduced the average duration of corrective maintenance by five times and halved related incidents (Bazán Montalto et al., 2024). In recent construction projects (2021-2024), the application of Lookahead and ICE sessions allowed achieving 84% compliance in deliveries, exceeding the minimum limit of 75% (Merino Chocano et al., 2024). Likewise, in the modeling of streets in Cajamarca, the VDC-BIM methodology covered 78.57% of the processes, compared to 21.43% of the traditional methodology (Ocas & Merma Gallardo, 2023). The 247 and Plaza 27 projects mentioned in (Jiménez Rodríguez et al., 2022), where the use of 3D as-built models improved decision making and communication between stakeholders. In addition, the project of the Ministry of Interior (MININTER) managed to reduce problems in BIM models, meeting 70% of the objectives set out in ICE sessions, (Prado, 2021). Finally, in projects such as the Miraflores district and the Alameda Rimac megacomplex, a 27% increase in productivity, better team communication and reduction in execution times were reported (Quiso et al., 2021). These cases are summarized in Table 4 along with the methodology implemented and the benefits obtained from each project by implementing VDC and Lean.

Table 4: Peru projects with VDC & Lean

Projects	Implemented Methodology	Benefits Obtained	Citations
University of Lima Laboratories	IFMS (VDC + Lean)	Reduction in corrective maintenance duration, 50% fewer incidents, 73% acceptance	(Bazán Montalto et al., 2024)
Construction Projects (2021-2024)	VDC, Lookahead	84% delivery compliance, 25% improvement in file delivery time.	(Merino Chocano et al., 2024)
Streets in Cajamarca	VDC-BIM	78.57% reach coverage compared to 21.43% for traditional methods.	(Ocas & Merma Gallardo, 2023)
Construction Projects (Grimaldo 247 y Plaza 27)	VDC, Models 3D As-Buil	Better decision-making, fluid communication between stakeholders.	(Jiménez Rodríguez et al., 2022)
Women's Emergency Center (CEM)	VDC-BIM	70% of objectives met, reduction of problems in BIM models.	(Prado, 2021)
Multi-family project in Miraflores and Rímac	VDC, Lean Construction	Productivity increased by 27%, communication improved, and activity time was reduced.	(Quiso et al., 2021b)

CONCLUSIONS

This research identified the main challenges and benefits in the implementation of the VDC and Lean methodology according to the surveyed professionals. In addition, this study highlighted the high frequency of use of tools such as the Last Planner System, evidencing their relevance and effectiveness in planning, control, risk management, and process optimization. A key contribution of this research is the identification of a new challenge not previously reported in the literature, based on the specific context of Peruvian construction projects. Although VDC and Lean Construction can be implemented independently, their integration offers a structured approach to reducing waste, improving planning accuracy, and increasing efficiency in construction projects. To encourage their adoption, it is recommended that companies provide training programs focused on their practical application. Additionally, organizations should establish clear guidelines to integrate both methodologies into project workflows, ensuring consistency and effectiveness. The research also contributed to the understanding of implementation, highlighting key benefits observed. This study establishes a solid foundation for future research to explore strategies for adapting these tools to future construction projects. It is recommended that the survey be extended to a larger number of practitioners and that further research be conducted to evaluate the economic and social impact of VDC and LC on projects of different scales and types, as well as to develop innovative approaches to optimize implementation and maximize benefits.

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