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Development of a collaborative design management system for enhancing building project efficiency

Desarrollo de un sistema de gestión de diseño colaborativo para mejorar la eficiencia de los proyectos de construcción

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Abstract

The construction industry often faces substantial challenges during the design phase, characterized by poor communication, inadequate documentation, and inefficient information management. These issues create a need for more effective tools to manage the complexity of design processes in building projects. To address this gap, this study proposes the development of a Collaborative Design Management System (CDMS) aimed at improving communication, coordination, and overall performance in multidisciplinary design teams. The CDMS integrates methodologies such as Lean, Agile, and Building Information Modeling (BIM) to optimize workflows, facilitate information exchange, and track performance through established indicators. The research is structured using the Design Science Research Method (DSRM), encompassing problem identification, literature review, system design, and implementation in real-world building projects. Data were collected from industry workshops and case studies, ensuring a practical basis for system development. The expected results include enhanced coordination, more efficient information flow, and improved design quality, contributing to a more collaborative and efficient approach to design management. These findings offer a practical framework for future applications aimed at optimizing collaboration in design projects. Future research should focus on broader implementation, customization for different project scales, and ongoing refinement of system functionalities to meet the evolving demands of the construction industry.

Keywords: Collaborative management; design; building; Lean; BIM.

Resumen

La industria de la construcción a menudo enfrenta desafíos sustanciales durante la fase de diseño, caracterizados por una comunicación deficiente, documentación inadecuada y una gestión de la información ineficiente. Estos problemas crean la necesidad de herramientas más efectivas para gestionar la complejidad de los procesos de diseño en proyectos de construcción. Para abordar esta brecha, este estudio propone el desarrollo de un Sistema de Gestión de Diseño Colaborativo (CDMS) destinado a mejorar la comunicación, la coordinación y el desempeño general en equipos de diseño multidisciplinarios. El CDMS integra metodologías como Lean, Agile y Building Information Modeling (BIM) para optimizar los flujos de trabajo, facilitar el intercambio de información y realizar un seguimiento del desempeño a través de indicadores establecidos. La investigación se estructura utilizando el Método de Investigación de Ciencias del Diseño (DSRM), que abarca la identificación de problemas, la revisión de la literatura, el diseño de sistemas y la implementación en proyectos de construcción del mundo real. Los datos se recopilaron de talleres de la industria y estudios de casos, lo que garantizó una base práctica para el desarrollo del sistema. Los resultados esperados incluyen una mejor coordinación, un flujo de información más eficiente y una mejor calidad del diseño, contribuyendo a un enfoque más colaborativo y eficiente para la gestión del diseño. Estos hallazgos ofrecen un marco práctico para futuras aplicaciones destinadas a optimizar la colaboración en proyectos de diseño. Las investigaciones futuras deberían centrarse en una implementación más amplia, la personalización para diferentes escalas de proyectos y el refinamiento continuo de las funcionalidades del sistema para satisfacer las demandas cambiantes de la industria de la construcción.

Palabras clave: Gestión colaborativa; diseño; edificio; Inclinarse; BIM.

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1. Introduction

The architecture, engineering, and construction (AIC) industry has been defined as a complex and seemingly unpredictable business involving different stakeholders with diverse interests. Over the years, most projects in this industry have shown poor performance (Esa et al., 2014). This has led the industry to seek to improve its competitiveness through the application of good management practices, advanced technologies, and resource optimization (Brozovsky et al., 2024); (El-Mashaleh et al., 2007). In this context, the design phase of building projects emerges as a critical area that needs efficient management to ensure the success of the project and the satisfaction of all involved (Economist Intelligence Unit, 2015).

The design phase of building projects, due to its cyclical nature and the involvement of multiple specialties (architecture, structures, mechanical, electrical, etc.), presents a complexity that often results in communication problems, poor documentation, and inefficient information management, which negatively impacts project performance (Baiden et al., 2006); (Ng and Tang, 2010). Moreover, it is recognized as a critical area in the performance of construction projects, as unresolved problems at this stage often lead to cost overruns and delays in later stages (Salvatierra et al., 2019). Thus, indicators such as redesign cost or the percentage of additional time spent to resolve interdisciplinary inconsistencies are metrics that show the importance of efficient design management (Herrera et al., 2019); (Kärnä and Junnonen, 2017). In addition, recent studies such as (Pérez et al., 2024), have focused their research on analyzing these problems in the context of design, the authors analyzed the influence of Lean Construction tools and BIM uses in mitigating the main factors that generate variations in the construction schedules of residential projects in two mixed-use residential projects in Bogotá, Colombia-one completed and one in progress. Their findings showed that 33% and 20% of the delays in these projects were not recoverable due to design changes made by the owner or designers during execution.

Although methodologies such as BIM, Lean, and Agile have been introduced to improve the management of building projects, they face significant challenges in the design phase. BIM, for example, despite its ability to manage information throughout the project life cycle, faces barriers related to the management of people and processes (Aliu and Aigbavboa, 2021); (Arayici et al., 2011); (Phelps, 2012). Similarly, the application of Lean has been limited at this stage, with adapted tools that do not fully match the characteristics of the design (Daniel et al., 2015); (Formoso et al., 1998); (Herrera et al., 2020). Although useful in the software industry, Agile faces difficulties in its implementation in building projects without the help of virtual models (Poudel et al., 2020). Additionally, in the design phase of building projects, it is not common practice to measure performance through specific indicators despite their importance in the continuous improvement of the process (Salvatierra, Galvez, et al., 2019). The lack of a culture of assessing design performance and its future consequences limits the ability of organizations to identify and address inefficiencies (Herrera et al., 2019); (Kärnä and Junnonen, 2017).

This paper presents a research proposal for the development of a Collaborative Design Management System (CDMS) for building projects, integrating principles of Lean, Agile, and BIM methodologies. The CDMS aims to improve the efficiency, coordination, and performance of multidisciplinary design teams through structured workflows, technological tools, and performance indicators. The research proposes to use the Design Science Research Method (DSRM), which encompasses five stages: problem identification, literature review, system development, implementation in real projects, and evaluation through performance indicators and stakeholder feedback. Data collection was conducted through workshops with industry professionals and case studies in building design projects. The expected results seek to substantially improve project coordination, information flow, and overall design quality, providing a practical framework for future applications to improve collaboration and efficiency in design project management. Therefore, this work proposes a comprehensive solution to the current problems in the design management of building projects, using a collaborative approach that integrates the best practices of Lean, Agile, and BIM methodologies to optimize the processes and results in the design phase.

BIM, Lean and Agile offer complementary approaches to address challenges in the design phase of building projects. BIM allows the centralization and accessibility of project information through a shared digital model, which facilitates coordination between disciplines and reduces communication errors and duplication of tasks (Azhar, 2011); (Eastman et al., 2008). Lean focuses on minimizing waste and improving design efficiency through detailed planning and adapting tools such as the Last Planner System for the design environment, which helps manage uncertainty and frequent changes in this phase (Ballard, 2000); (Biotto et al., 2022). Finally, Agile introduces continuous feedback loops and rapid iterations, adapting to the cyclical nature of design and allowing flexibility to adjust requirements as the project evolves. The current practice of managing the design phase in building projects is fraught with recurring issues, such as poor communication, insufficient documentation, and inefficient information flow. These shortcomings often lead to disorganized workflows, delayed decision-making, and coordination breakdowns

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between different design disciplines. Although methodologies such as BIM, Lean, and Agile have been developed to address these challenges, each faces its shortcomings that limit its effectiveness in the design phase.

For instance, while BIM has been widely adopted to manage information throughout a building's life cycle, its full potential in the design phase remains untapped due to difficulties in managing the people and processes involved. Many organizations focus heavily on the technical capabilities of BIM, overlooking the collaborative and social dynamics required to optimize its use (Arayici et al., 2011); (Herrera et al., 2021). his has resulted in situations where BIM models are developed in isolation, with limited input from key stakeholders, leading to inconsistencies and misunderstandings later in the project (Aziz et al., 2024); (Phelps, 2012).

Similarly, Lean methodologies have been successfully implemented in the construction phase but have struggled to gain traction in the design phase. Tools like the Last Planner System, while effective in construction, do not fully account for the iterative nature of the design process, where some level of rework and iteration can add value (Daniel et al., 2015). However, its application in the design phase has been limited, using mainly standardized tools that do not fully adjust to the dynamic characteristics of this phase (Biotto et al., 2022b); (Formoso et al., 1998); (Mollasalehi et al., 2016). For example, while in construction, iterations and rework are considered losses, in design, some iterations may add value, which requires a different approach to loss management (Mujumdar and Maheswari, 2018).
Agile methodologies, though widely embraced in the software industry, face challenges in the construction context, especially during the design phase. Agile's reliance on iterative cycles and constant client feedback does not easily align with the structured workflows required for building design without the integration of virtual models like BIM (Mohammed and Karri, 2020); (Poudel et al., 2020). Furthermore, Agile's flexibility can sometimes conflict with the regulatory and contractual constraints typical in construction projects, where significant changes during the design phase are less feasible.

In addition to these methodological challenges, the social and collaborative aspects of design management are often neglected. Design teams typically comprise specialists from different disciplines, often working in separate organizations. This lack of integration leads to miscommunication, trust issues, and inefficient decision-making processes. For example, architects and structural engineers may have conflicting objectives or timelines, leading to coordination breakdowns (Retamal et al., 2020). Without a system to foster interaction, collaboration, and shared understanding among these stakeholders, the design phase can easily become fragmented and inefficient.

Moreover, the absence of performance indicators in the design phase is another critical gap. While it is common to measure project performance during construction using metrics related to cost, time, and quality, these indicators are seldom applied during design (Salvatierra et al., 2019). This lack of measurement makes it difficult to identify inefficiencies or areas for improvement in real-time, limiting the potential for continuous process enhancement.

Given these challenges, there is a clear need for a system specifically designed to address the complexities and unique characteristics of the design phase in building projects (Herrera, et al., 2019). The Collaborative Design Management System (CDMS) proposed in this study aims to fill this gap by integrating Lean, Agile, and BIM principles into a cohesive framework that facilitates communication, coordination, and performance measurement among design teams.

2. Proposal of development

Given the above, it is necessary to develop a collaborative management system for the design of building projects, which is not a simplified adaptation of tools for this phase of the project but rather is created with an understanding of the characteristics of the design phase of building projects. To develop a collaborative design management system, it is necessary to understand the particularities and typical problems that building project design teams have. This includes understanding its stages, requirements, milestones, and participants, among other elements that are unique to it (Agyekum and Knight, 2017); (Chan et al., 2001); (Olanrewaju et al., 2017).

The design phase in construction projects is characterized by a dynamic and complex nature, marked by the need to coordinate multiple disciplines that must be integrated into a cohesive and functional design. Specific complexities include frequent changes in client requirements, the continuous iteration required to adjust the design to current regulations and safety standards, and the management of information across teams with diverse specializations and perspectives. Additionally, the design process faces challenges in synchronizing updates in the BIM model,

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as each change can impact various areas of the project, necessitating an efficient collaborative management system to minimize errors and rework.

Thus, the collaborative design will contemplate the planning of the design and a management system aligned with the Lean philosophy, where the principles and tools of agile project methodologies and the uses of the BIM methodology are applied (Park et al., 2016). It can be used with different contracting strategies, i.e., from integrated projects (IPD) to traditional Design-Bid-Build (DBB) projects. While collaborative design may be best applied with IPD contracting strategies, it is possible to apply the collaborative management system to DBB contracts (Mesa et al., 2016).

The collaborative design management system (CDMS) will include processes for initiating, planning, executing, monitoring and controlling, and closing the design phase of the building project (Lester, 2014). Thus, following the Lean principles for project design and understanding the iterative and dynamic process characteristics of an agile project.

• Planning processes will include tools for scheduling, budgeting, assessing scope and quality, and defining instances of project interaction and collaboration (Herrera et al., 2020). In addition, given the iterative and dynamic nature of this type of project, planning is understood as a systematic, gradual, and collaborative process (Reifi and Emmitt, 2013) where creative and standardized planning processes meet.
• The execution processes will include technological tools to make both the design process and the subsequent stages of construction more efficient. BIM, Geographic Information Systems, point clouds, and photogrammetry, among others, are potentially useful tools for these purposes (Kassem et al., 2014). Project execution will be systematically compared with project planning through monitoring and control processes.
• The monitoring and control processes will include a proposal for performance indicators associated with compliance with deadlines, costs, productivity, and commitments, among others. In addition, these processes should include systematic review and coordination between specialties, as well as recurrent participation of the client (or its representative) in progress meetings. In addition, indicators will be proposed to evaluate the design's impact on the building's construction stage (Herrera et al., 2019).

For the development of the Collaborative Design Management System (CDMS), the Lean, Agile, and BIM methodologies were specifically selected due to their complementary approaches and key contributions to improving the design phase in construction projects. Lean was chosen for its ability to reduce waste and optimize process efficiency, addressing common workflow issues in design through production control tools such as the Last Planner System (Ballard, 2000); (Biotto et al., 2022a). Agile is incorporated for its focus on flexibility and continuous adaptation, enhancing the team’s ability to respond to changing requirements swiftly and allowing for rapid iterations essential in a design environment. Lastly, BIM is integrated as a central methodology for interdisciplinary collaboration, enabling centralized information management through shared digital models that reduce errors and improve coordination among the different project teams (Azhar, 2011); (Eastman et al., 2008).

To evaluate the effectiveness of the CDMS, five performance metrics will be used, aligned with the system's objectives. The coordination efficiency metric measures the frequency and quality of communication across design disciplines, considering the number of coordination issues detected and the time spent resolving them. The second metric, design errors and rework tracks the frequency and severity of design errors and the amount of rework required, including the time and cost associated with their correction. To assess process agility, the time to complete design iterations metric measures the time required for each design iteration and the number of iterations needed. Stakeholder satisfaction is evaluated through surveys and interviews with clients, contractors, and design team members, focusing on their perception of the design process quality. Lastly, the BIM usage and information flow metric monitors the adoption and accuracy of information exchange through BIM, measuring the precision of shared data and the frequency of updates to the BIM model.

Unlike traditional management systems, a greater emphasis on collaboration is proposed, understanding the dynamic and complex nature of this phase of the building project. Given the nature of the design teams for building projects, where there are several specialists, generally belonging to different companies, it is essential to generate and promote interaction and collaboration strategies. Thus, within the interaction strategies, the system would include different instances for the generation of interaction, for example, work information flow, planning, collaboration, problem-solving, decision-making, trust, and learning (Herrera et al., 2020). Additionally, interaction will be approached from the perspective of commitment management and shared understanding, which is a key measure of the effectiveness of communication in work teams (Retamal et al., 2020). When team members carry out collaborative work, it is accompanied by systematic discussion and negotiation, where shared understanding is particularly important in generating agreements among design team members and developing proper commitment management (Kleinsmann et al., 2012). Commitment management is a way of understanding relationships between team members from the

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perspective of linguistic action, which includes four speech acts for generating reliable commitments. The four speech acts are request, negotiation, statement of compliance, and statement of satisfaction (Cash et al., 2017). So, the collaborative design management system will include the perspective of compromise management among all the design team's participants.

After the creation of the collaborative design management system, its performance will be evaluated in terms of compliance with organizational goals, performance indicators, and perception measures of the different stakeholders involved in the design process of a building project. To do this, it is proposed that four projects be evaluated in the design phase. Each project should have a different level of implementation of BIM uses during the design phase to understand the importance of this technological support methodology in the implementation of the collaborative management system and the performance of the project. Additionally, projects that follow the national BIM standard for public projects (in addition to the four previously evaluated) will be evaluated to analyze the impact of this guide on the performance of the projects and also to identify the gaps between the national BIM standard and the collaborative management system for design.

3. Framework proposal for development

In project design management, there are complex and multidimensional challenges that require innovative, practical, and theoretically grounded solutions. To address these research challenges, the Design Sciences Research Method (DSRM) will be used, as it allows for a structured process that not only focuses on the creation of a collaborative management system but also the rigorous evaluation of its effectiveness. DSRM, or constructive research, is a form of descriptive research that has two fundamental activities: creating artifacts to serve human purposes and evaluating the performance of their use (Da Rocha et al., 2012). DSRM is divided into five stages: (1) identify and understand a specific problem; (2) Obtain a deep theoretical and practical understanding of the issue; (3) innovate with an idea to solve the problem; (4) evaluate the solution; and (5) reflect and analyze the theoretical and practical contribution (Lukka, 2003). Each of the stages summarized in (Figure 1) is explained below.

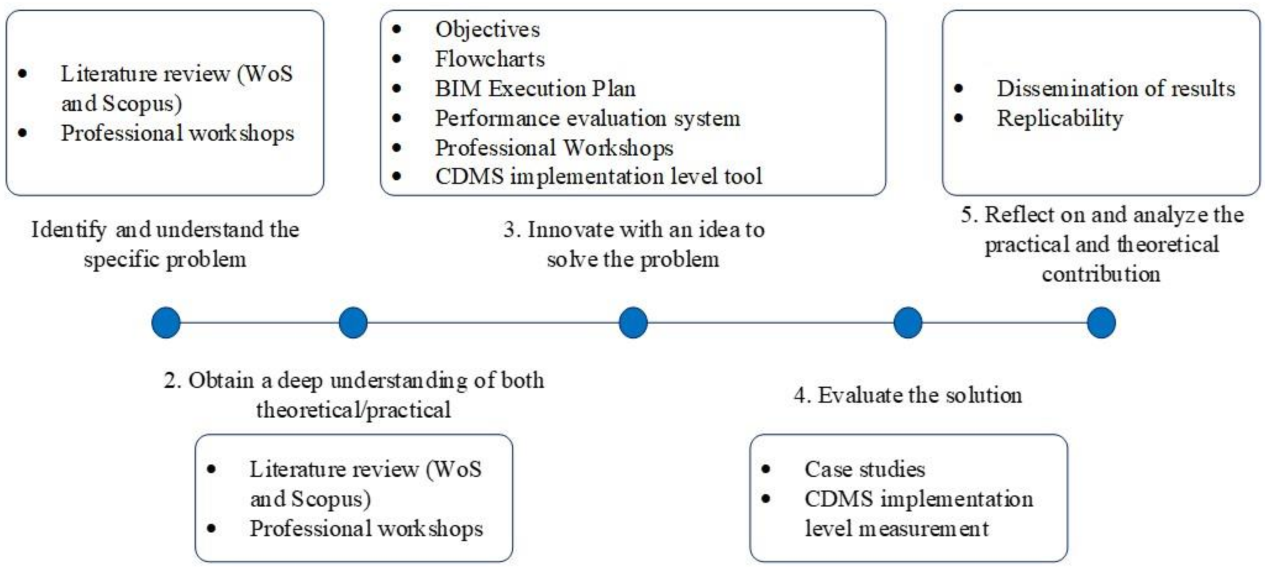

Figure 1. Methodological implementation scheme.

3.1 Identify and understand a specific problem

To develop this stage, first, a literature review will be conducted in specialized architecture, engineering, and construction journals and major conferences between the years 2010 and 2024; the search will be conducted in the following libraries: Engineering Village, Web of Science, and Scopus. The search topics will be the following: "design management," 'design planning,' 'design evaluation,' 'design control,' 'problems in design,' and 'design management challenges.' Articles will be selected by applying the following inclusion/exclusion criteria: (1) focus on building design, (2) present specific problems, and (3) focus on design management. A summary table with the information extracted from each document will be used to control and collect the information. To identify and understand the specific problem from the literature review, network analysis, and word co-occurrence techniques will be applied to determine research fronts.

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Then, to validate the specific problem, five workshops will be held with professionals involved in the design of building projects. In this first round of workshops, we will work with each type of stakeholder separately, i.e., five different workshops will be held with (1) clients (real estate), (2) architects, (3) structural engineers, (4) other specialists, and (5) project coordinators and BIM coordinators. Between 5 and 10 professionals with more than five years of experience in building design projects should participate in each workshop. Professionals participating in the Chilean Chamber of Construction of Chile, the Association of Structural Engineers, the Association of Architectural Offices of Chile, and BIM Forum Chile will be invited. Each workshop will address the main problems detected in the literature review and will understand how this problem affects the different people involved in the design teams of building projects.

3.2 Obtain a deep theoretical and practical understanding of the subject

To develop this stage, we will first conduct a literature review in specialized journals of architecture, engineering, construction, and project management, and major conferences between the years 2010 and 2024; the search will be conducted in the following libraries: Engineering Village, Web of Science, and Scopus. The search topics will be the following: "collaborative design," 'design planning,' 'BIM design,' 'Lean design,' 'agile design,' 'management systems, and 'performance indicators.' Articles will be selected by applying the following inclusion/exclusion criteria: (1) focus on building design; (2) proposed practices, tools, technologies, or indicators; and (3) focus on social phenomena of interaction and collaboration. A summary table with the information extracted from each document will be used to control and collect the information. Additionally, network analysis and word co-occurrence techniques will be applied to obtain a deep theoretical understanding of the reported approaches to collaborative management systems for building project design.

Then, to validate the specific problem, two workshops will be held with professionals involved in the design of building projects and one workshop with researchers specialized in the design of construction projects. The first workshop with professionals will include clients (real estate), project coordinators, and BIM coordinators. The second workshop will include professionals such as architects, structural engineers, and other specialists. Each workshop should be attended by 5 to 10 professionals with more than five years of experience in building design projects. Professionals participating in the Chilean Chamber of Construction of Chile, the Association of Structural Engineers, the Association of Architectural Offices of Chile, and BIM Forum Chile will be invited. In the workshop with researchers specialized in the design of construction projects, academics with more than five years of research experience from national and foreign universities will be invited. Each workshop will address the main management practices for the design of building projects. In addition, a comparative study will be made between the three groups of professionals, i.e., managers, designers, and researchers.

3.3 Innovate with an idea to solve the problem

In this stage, the researcher and his team will create a collaborative management system for the design of building projects. The system will include a set of best practices, tools, technologies, and indicators for planning, executing, and controlling each of the sub-stages of building design. The following elements will be proposed for each design sub-stage (conceptual design, preliminary design, detail design, and construction documentation):

• Sub-stage objectives: The goal and specific objectives of each sub-stage will be included. For this, the SMART (Specific, Measurable, Attainable, Relevant, Timely) objective creation methodology will be used.
• Activity flowchart: A graphical notation will be used to describe the logic of the sub-stage steps. Tools such as the Business Process Model and Notation (BPMN) and value stream maps (VSM), among others, will be explored. The flowchart will be created based on the principles and recommendations of the Lean and Agile philosophy. Therefore, the different participants, interaction and collaboration mechanisms, information flows, and review instances will be included. Within the activities proposed in each flowchart, a distinction will be made between the base or minimum activities to execute the system and the recommended or optional activities, which are proposed to make the design process even more productive.
•BIM Uses: BIM uses, and deliverables required for the sub-stage will be proposed. For this purpose, the BIM uses framed in the National BIM Standard for public projects in Chile will be proposed, which are also the same as those proposed by the BIM planning and execution guide developed by the University of Pennsylvania. At this point, the minimum and ideal level of automation of each BIM use will be defined, considering that each BIM use can have different levels of scope, automation, and development, as proposed by (Rojas et al., 2019) in their instrument to measure different levels of development of each BIM use during the design and planning phases of construction projects and their applications in other countries, for example, Ecuador (Arellano et al., 2021).

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• Performance indicators: Sub-stage performance indicators will be included, which should be aligned with the objectives of the sub-stage and the fulfillment of the sub-stage planning. The indicators will include quantitative indicators and measures of perception of the performance of the different stakeholders involved in the sub-stage. Performance will be evaluated in terms of productivity and organizational terms. The indicators associated with productivity will have to do with the use of resources, costs, compliance with the schedule, and quality, among others. Organizational performance indicators will be associated with measures of the perception of team members and the study of interactions through the analysis of the team's social networks, using as a basis a method to evaluate the interactions of design teams in construction projects.

The four elements mentioned in the previous point will be integrated into each sub-stage. In addition, the system will define a system of concatenation and continuous flow between each sub-stage of the design phase of the building project.

The collaborative management system will be developed gradually and iteratively by the research team, so several deliverables equivalent to the sub-stages defined for the design phase will be proposed. Each deliverable will be reviewed and fed back by a group of professionals and researchers with at least five years of work and/or research in building projects. Thus, the collaborative management system will be evaluated and improved in several instances by the expert committee. This iterative and incremental nature is typical of agile projects for the creation of artifacts and, at the same time, is part of the methodological approach of DSRM.

In addition, during this stage of the research project, a second artifact will be created to evaluate the level of implementation of the collaborative management system for building design. This artifact will consist of an evaluation rubric of different criteria, which will allow the design teams that use the system to self-diagnose themselves and identify their achieved activities and areas of growth. This instrument will be created by the research team and validated by a mixed group of professionals and researchers.

3.4 Evaluate the solution

In this stage, the researcher and his team should evaluate the performance of the collaborative management system for building design. To evaluate the solution, first of all, a third artifact will be created, which will allow us to evaluate the impact, benefits, and difficulties of the system implementation through quantitative performance indicators, interaction network analysis, and user perception.

Then, four real case studies will be analyzed, who are willing to participate in the research and to share the project information (always safeguarding confidentiality by following the guidelines of the University's ethics committee). In each case study, the researcher or a member of the work team will participate as a facilitator of the system, so three workshops will be held to train the members of the design teams of each of the projects to be evaluated, applying the participatory action research strategy. Additionally, the researcher should participate as a system facilitator during the entire design phase of the building projects (between 4 and 8 months). During this time, the level of implementation of the system and its impact on the design team will be evaluated.

It is proposed that each of the four case studies will have different levels of development of the BIM technology support methodology. For this, an initial survey of the BIM uses that are intended to be developed in the project will be made, and then an assessment of the level of development of each BIM use will be made through the BIM Uses Assessment (BUA) tool (Rojas et al., 2019). In this way, it will be possible to understand the value delivered by the advanced use of BIM in the collaborative management system.

Additionally, at least two projects will be evaluated using the national BIM standard for public projects in Chile, in which the researcher and his team will only participate as observers, and no workshop will be held for the implementation of the system. In these two projects, the same indicators will be measured, and the same instruments will be applied as in the four real case studies. This information will then be used to analyze the scope and impact of the national BIM standard for public projects on project performance. Additionally, this information will allow us to detect gaps between the recommendations of the national BIM standard and the collaborative management system proposed in this research.

3.5 Reflect and analyze the practical and theoretical contributions

At this stage, the researcher, together with the research team and a group of experts, should reflect on the contribution to knowledge and the practical value of the collaborative management system for the design of building projects. Additionally, during this reflection, the limitations of

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the system and the research should be recognized. Finally, the broader applicability of the solution to other types of projects, such as non-housing construction, industrial works, roads, etc., should be considered.

4. Results

The evaluation of the Collaborative Design Management System (CDMS) is expected to yield measurable improvements in several key areas of the design process (See (Figure 2)). The results will be analyzed using carefully selected performance indicators that reflect both the efficiency of the system and its impact on overall project outcomes. Additionally, the CDMS will be compared to existing project management systems to highlight its advantages.

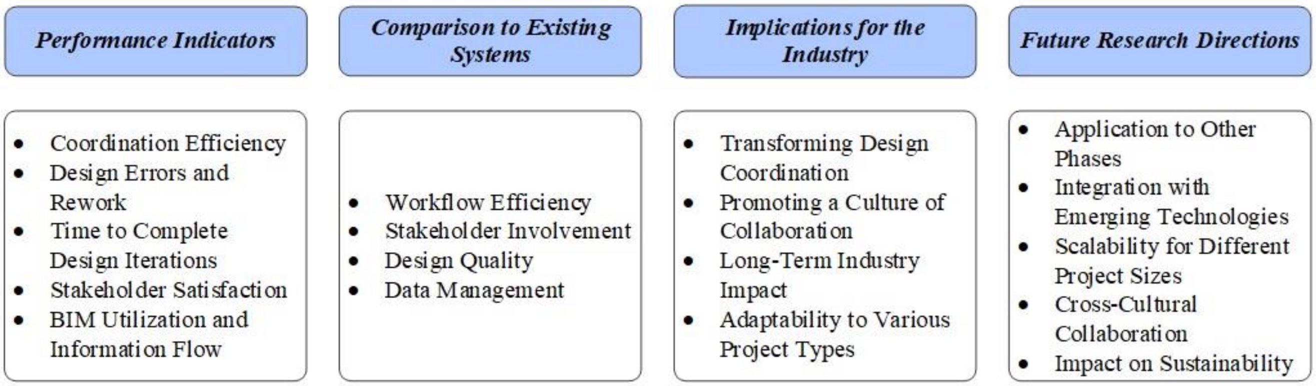

Figure 2. Measurable improvements in the evaluation of the Collaborative Design Management System (CDMS).

4.1 Performance Indicators

The following performance indicators will be used to evaluate the effectiveness of the CDMS:

1. Coordination Efficiency:

• Definition: Measures the frequency and quality of communication between different design disciplines (e.g., architects, structural engineers, mechanical engineers).

• Rationale: Coordination is a critical factor in the success of the design phase. Poor communication often leads to design errors, delays, and additional costs. The CDMS aims to streamline coordination through structured workflows and collaboration tools.

• Measurement: The number of coordination issues raised, time spent resolving coordination problems, and feedback from team members on communication effectiveness.

2. Design Errors and Rework:

• Definition: Tracks the number of design errors detected and the amount of rework required during the project.

• Rationale: Design errors can significantly impact the project timeline and budget. By improving collaboration and information flow, the CDMS is expected to reduce errors and the need for rework.

• Measurement: The frequency and severity of design errors, as well as the time and cost associated with correcting them.

3. Time to Complete Design Iterations:

•Definition: Measures the time taken to complete each design iteration.

• Rationale: Efficient iterations are crucial to delivering the project on schedule. The CDMS promotes faster iteration cycles through the use of agile methodologies and real-time feedback.

•Measurement: The time required to move from one design stage to the next and the number of iterations necessary to finalize the design.

4. Stakeholder Satisfaction:

• Definition: Assesses the satisfaction levels of all stakeholders, including clients, contractors, and design team members, regarding the design process.

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• Rationale: Successful design management is not only about meeting technical requirements but also ensuring that stakeholder expectations are met. The CDMS focuses on continuous feedback and client involvement, aiming to enhance satisfaction.
• Measurement: Surveys and interviews with stakeholders, focusing on communication, design quality, and project outcomes.

5. BIM Utilization and Information Flow:
• Definition: Tracks the extent to which BIM is used effectively to manage project data and facilitate information sharing between disciplines.
• Rationale: BIM is a central component of the CDMS, allowing for integrated data management. Effective use of BIM should lead to more accurate information flow and better decision-making.
• Measurement: The level of BIM adoption, the accuracy of data shared across teams, and the number of BIM model updates.

4.2 Comparison to Existing Systems

The CDMS will be compared to traditional project management systems used in the design phase, such as manual coordination methods, isolated use of BIM without integrated workflows, and standard Lean or Agile tools not specifically tailored to design processes. The key advantages of the CDMS include:
• Workflow Efficiency: Traditional systems often rely on fragmented workflows where each discipline works in isolation, leading to communication breakdowns. The CDMS integrates Lean, Agile, and BIM to create a seamless workflow that reduces delays and miscommunication.
• Stakeholder Involvement: Existing systems often limit client involvement to periodic check-ins. In contrast, the CDMS encourages continuous client feedback, ensuring that the design evolves according to stakeholder needs and reducing the risk of late-stage changes.
• Design Quality: While current systems often fail to prevent design errors early on, the CDMS's real-time collaboration tools and structured workflows help identify issues sooner, improving overall design quality.
• Data Management: The integration of BIM in the CDMS allows for more effective data sharing and reduces the time spent searching for information, a common problem in traditional systems.

4.3 Implications for the Industry

The implementation of the Collaborative Design Management System (CDMS) represents a significant shift in how the construction industry approaches the design phase of building projects. Traditionally, the industry has struggled with inefficiencies in this phase, often leading to project delays, cost overruns, and communication breakdowns. The CDMS offers a solution by:

Transforming Design Coordination: By integrating Lean, Agile, and BIM, the CDMS addresses the challenges of design phase coordination, allowing for better alignment between stakeholders. This can lead to significant reductions in design errors, quicker decision-making, and improved project outcomes.

Promoting a Culture of Collaboration: The CDMS encourages a collaborative culture in the construction industry, shifting away from siloed operations. The system's reliance on shared information, real-time feedback, and regular communication fosters teamwork across disciplines, ultimately improving project performance.
Long-Term Industry Impact: In the long term, widespread adoption of the CDMS could lead to standardization of collaborative design management practices, potentially influencing industry guidelines and norms. Over time, this could contribute to higher-quality project outcomes, reduced construction times, and lower costs.

Adaptability to Various Project Types: While initially focused on building projects, the principles of the CDMS could be adapted to other sectors, including industrial, commercial, and infrastructure projects. This adaptability makes the system applicable to a wide range of construction projects, further increasing its potential impact on the industry.

4.4 Future Research Directions

Although the CDMS focuses on addressing challenges in the design phase, there are several areas of potential expansion that future research could explore:

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Application to Other Phases: Future studies could explore the extension of the CDMS to the construction and post-construction phases. Integrating the CDMS across the full project life cycle would provide a seamless management tool, ensuring consistency from design to project delivery.

Integration with Emerging Technologies: The construction industry is evolving rapidly with the introduction of new technologies such as artificial intelligence (AI), machine learning (ML), and virtual reality (VR). Research could investigate how the CDMS could incorporate these technologies to further enhance design management, particularly in areas such as clash detection, design optimization, and immersive stakeholder presentations.

Scalability for Different Project Sizes: While the current research focuses on larger building projects, future studies could examine how the CDMS could be scaled for small- and medium-sized projects. Understanding the system's adaptability across different project scales will allow for broader application.

Cross-Cultural Collaboration: As the construction industry becomes more global, cross-cultural collaboration will increase. Research could explore how the CDMS might support projects involving teams from different countries and cultures, ensuring effective communication and collaboration in multinational projects.

Impact on Sustainability: Given the growing importance of sustainability in construction, future research could examine how the CDMS can be adapted to prioritize sustainable design practices. This could involve integrating performance indicators that measure environmental impact, energy efficiency, and resource use throughout the design phase.

5. Conclusions

The expected results and theoretical contributions of this research include a better understanding of the current ways of managing projects in design phases and the main management and performance gaps. Additionally, it is expected to define a set of building project management principles that align with the main current management philosophies and methodologies, such as Lean, Agile, and BIM. In addition, there will be a better understanding of the social phenomena that are generated in the design teams of building projects. Finally, as a practical contribution, it will be possible to identify the benefits and challenges of implementing a collaborative management system for the design of building projects.

Complementarily, the practical value of this research has as its main protagonist the Collaborative Management System for the Design of Building Projects. The collaborative management system will allow real estate companies, construction companies, architecture, and engineering offices to implement a system that will include a proposal for a set of practices, tools, technologies, and indicators to make the design phase of building projects more efficient. In addition, this research project will provide a gradual implementation plan of the different practices and tools so that offices with different levels of technological automation can apply the collaborative management system. In this way, a roadmap will be proposed for the different organizations to gradually implement the collaborative management system for the design of building projects.

Additionally, a comparative study will be made between the projects where the collaborative management system for design is applied and the projects that are being designed with the national BIM standard for public projects in Chile; in this way, it will be possible to detect gaps between both strategies that will allow feedback and suggestions for improvements to the national BIM standard.

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