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AGILE MANAGEMENT AND BIM: ANALYSIS OF THE IMPACTS OF IMPLEMENTING BIM IN A STRUCTURAL DESIGN COMPANY FROM THE PERSPECTIVE OF AGILE METRICS

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Abstract: The adoption of BIM has transformed project management in the Architecture, Engineering and Construction (AEC) industry. This study analyzed the impacts of implementing BIM in a structural design company, using three agile metrics: *Work in Progress (WIP)*, *Lead Time* and *Throughput*. The combination of agile management and BIM aims to increase productivity and improve communication between teams. The results showed that, although advantages were identified in the implementation of BIM, such as efficiency in revisions and accuracy in quantities, challenges arose, including a high number of revisions, low maturity of BIM models, saturation of WIP, affecting workflow, as well as a lack of control procedures and insufficient training. In response, improvements were proposed at three levels: strategy, production and flow management, resulting in actions such as monitoring production through a *Kanban* board and agile metrics, aligning deliverables, developing plugins to automate manual processes, changing the BIM flow for modeling and detailing infrastructure and implementing audits. These initiatives have led to a 60% reduction in delivery failures and an increase of around 30% in the company's average turnover since 2023.

Keywords: Agile methods. Agile metrics. BIM (*Building Information Modeling*).

INTRODUCTION

The AEC industry is often seen as conservative in its adoption of new technologies, sticking to models and processes that have been established for decades [1]. However, the use of BIM as a project management tool has now become a worldwide reality [2]. BIM has transcended its initial role as a three-dimensional (3D) modeling technology, evolving into an integrated approach that aims to manage project data and information throughout the building's life cycle [3].

Despite the advantages offered by BIM, the successful adoption of this methodology faces significant challenges. Many organizations still prioritize meeting deadlines and requirements, but without effective planning and production management, compliance with contracts becomes unfeasible [4]. Effective processes are essential for success in construction projects, and it is in this context that Agile Methods can play a key role in managing these projects [5]. Although Agile Methods initially emerged in the software industry, their application extends beyond manufacturing and systems development, allowing companies to maximize resources and manage losses more efficiently [6] .

In this context, this study aims to assess the impact of adopting BIM on the workflow of an engineering design company, using the analysis of three agile metrics: *Work in Progress (WIP)*, *Lead Time* and *Throughput*. Identifying and implementing these metrics is crucial, as they provide a clearer and more accurate view of operational performance, helping the company to face the challenges inherent in integrating BIM into its processes. By focusing on performance measurement, this work seeks not only to understand the impacts of implementing BIM, but also to propose improvements aimed at optimizing workflow and, consequently, the company's results.

Analysis of the results has provided a deeper understanding of how the combination of BIM and agile metrics can transform project management in the AEC industry, contributing to a more efficient and effective approach that takes into account the specificities and challenges of implementing this new technology. With this, it is hoped that the lessons learned and improvements proposed will serve as a basis for future initiatives to adopt BIM in other companies in the sector, promoting a continuous evolution in the practice of architecture, engineering and construction.

THEORETICAL BACKGROUND

The theoretical basis of this study is made up of four main sections: BIM Methodology, Project Management in Engineering Companies, Integration between Agile Management and BIM and Agile *Frameworks*.

BIM METHODOLOGY

BIM is a methodology that goes beyond the tools and software used to draw up projects and budgets in the construction industry. According to Succar et al. (2012), BIM is a set of interactions between policies, processes and technologies that aim to digitally manage the design of a building throughout its life cycle.

The use of BIM has grown globally, driven by the search for greater productivity and efficiency throughout the construction value chain [7,8]. However, its implementation faces significant challenges. Resistance to change in organizational culture [9,1], the difficulty of making it compatible with existing schedules [8] and the lack of structuring of processes and information flows [2] are barriers that hinder the effective adoption of BIM.

PROJECT MANAGEMENT IN COMPANIES

In traditional project management, the focus is on extensive planning, which often results in excessive documentation and resistance to change. This model can be ineffective in projects with high uncertainty and complexity, where the rigidity of traditional approaches presents significant challenges [11]. The Agile Manifesto, on the other hand, introduced principles that prioritize collaboration and flexibility, promoting a culture of adapting to change rather than strictly following a plan [12].

Although the agile approach originated in software development, its practices are applicable to several areas, including construction [13]. Agile methodologies emphasize the interaction between individuals and the delivery of value to the client, allowing a faster response to needs and changes throughout the project [14]. The integration of agile management with BIM proposes multidisciplinary coordination, reducing rework and improving communication between the parties involved [15].

INTEGRATION BETWEEN AGILE MANAGEMENT AND BIM

The intersection between agile management and BIM promises a more efficient approach to project management, maximizing the benefits of both methodologies. BIM, in addition to serving as a repository of project information, transforms the way teams collaborate and communicate, providing a solid foundation for the implementation of agile practices [9,16,17].

Agile principles can maximize gains in the early stages of the project by improving the understanding of requirements, communication between stakeholders and the effectiveness of the team [18]. By combining these approaches, it is possible not only to reduce omissions and rework, but also to optimize project time and costs.

AGILE *FRAMEWORKS*

Kanban offers a smooth transition from traditional to agile management, functioning as a lean approach and a visual signaling system that integrates the production process [13]. It acts as a *framework* that provides a complete visualization of the workflow, identifying bottlenecks and work in progress [13]

Regarding the choice of metrics, for teams new to the agile universe, the analysis of *Work in Progress (WIP), Lead Time* and *Throughput* is fundamental. WIP represents uncompleted work that has already generated costs [13]. *Throughput* measures the number of deliveries completed per unit of time, while *Lead Time* refers to the total time of an item in the process, essential for managing delivery times [13].

According to Davis (2015), working with metrics in a *feedback* loop (Figure1) in parallel with the development flow will guarantee better decisions for the team and help improve communication throughout the organization.

RESEARCH METHODS

The research was conducted at a structural design company in Greater Florianópolis, which has been seeking to implement and improve BIM for around four years. The study used a quantitative and qualitative approach, focusing on analysis of BIM and CAD workflows, from the perspective of three agile metrics: *Work in Progress (WIP), Lead Time* and *Throughput*.

Initially, a comprehensive literature review was carried out on BIM and agile methodologies. Next, one of the company's main clients, NX Construtora, was selected for detailed analysis. The workflows in CAD and BIM formats were mapped using *Bizagi* software, which allowed the two processes to be visualized and compared.

To collect data on the performance of the flows, a *Kanban* board was used, configured as follows (Figure ,2 Figure3 and Figure4):

Tasks were monitored on a weekly basis over a period of eight weeks, which allowed the stages of project development to be visualized and to identify bottlenecks in the process. The metrics were applied based on Davis' (2015) guidelines on the *feedback* loop and the analysis of the results focused on identifying trends, difficulties and opportunities for improvement

Finally, based on the results obtained, improvement actions were proposed, such as the use of agile tools and training in BIM, with the aim of optimizing the workflow and reducing the difficulties identified

RESULTS AND DISCUSSIONS

The results of this study indicate that the adoption of BIM has brought significant improvements to the workflow of the company studied, especially in comparison with the previous CAD-based process.

However, several difficulties were also identified that impacted the effective implementation of BIM and the team's performance. Analysis of the three agile metrics - *Work in Progress (WIP), Lead Time* and *Throughput* - provided insight into the strengths and weaknesses of the new workflow.

METRICS ANALYSIS

Analysis of the WIP (Figure4) showed that, during the monitoring period, there was a significant backlog of items in progress, which overloaded the team and reduced delivery capacity.

The excess of items in progress was directly related to flaws in the planning and organization of tasks, resulting in unfinished projects remaining in the system for too long without substantial progress. As a consequence, the *Throughput* rate (Figure3) was low, which affected the company's ability to meet the deadlines agreed with its clients.

Lead time (Figure5), which measures the total time it takes to complete a task, also showed significant variations. In some cases, the time between starting and completing a task was much longer than expected, mainly due to blockages in the process, such as the lack of complete information to continue with certain steps.

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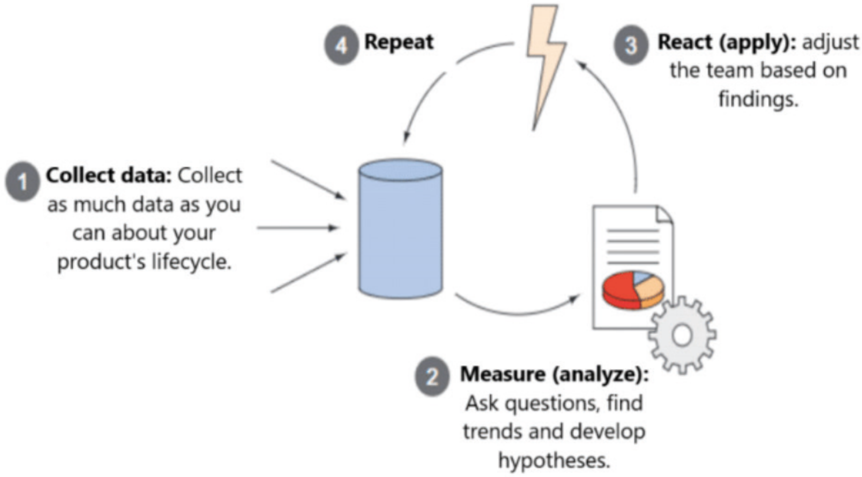

Figure1 : Feedback cycle

Source: Davis (2015).

Figure2 - *Kanban* board steps - Part 1 of 2

Source: The authors (2023)

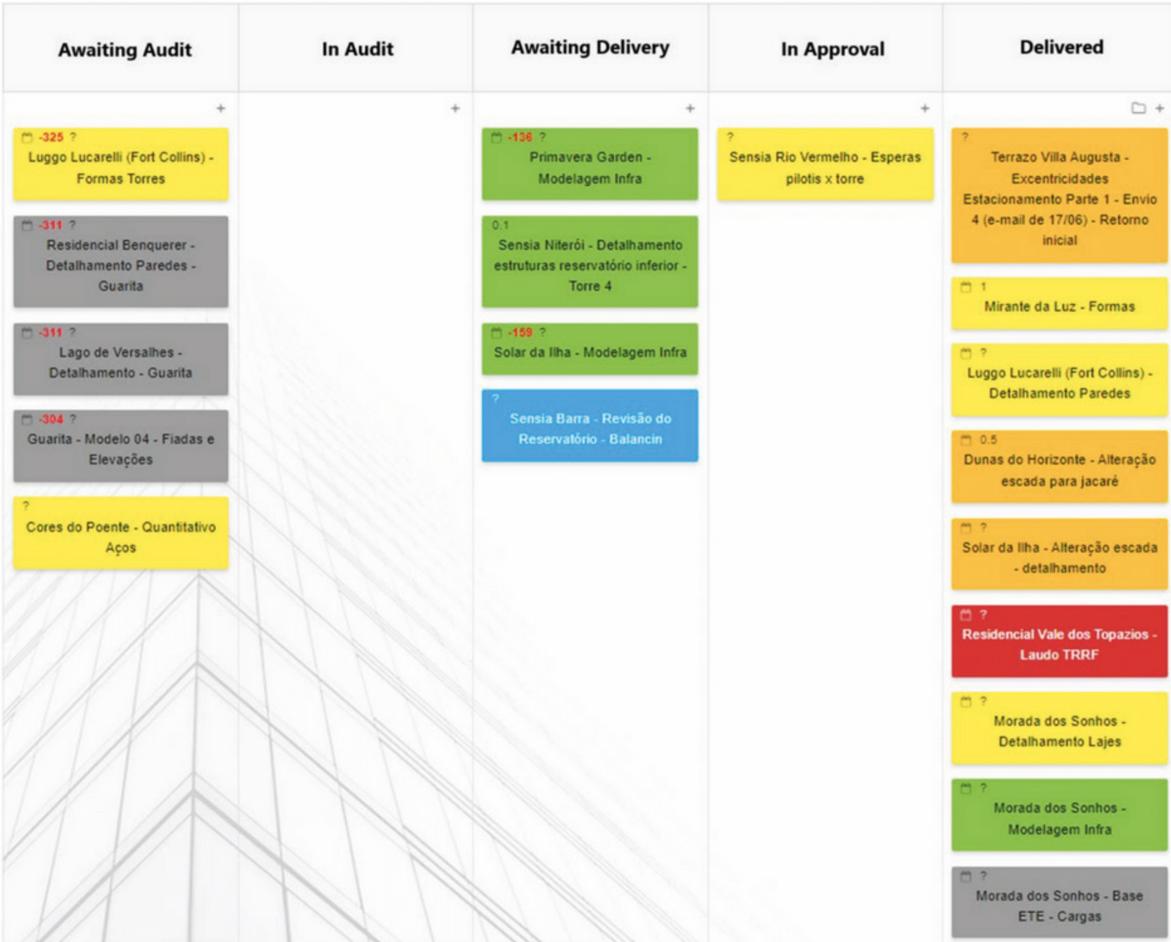

Figure3 - *Kanban* board steps - Part 2 of 2

Source: The authors (2023)

Figure4 - Card types

Source: The authors (2023)

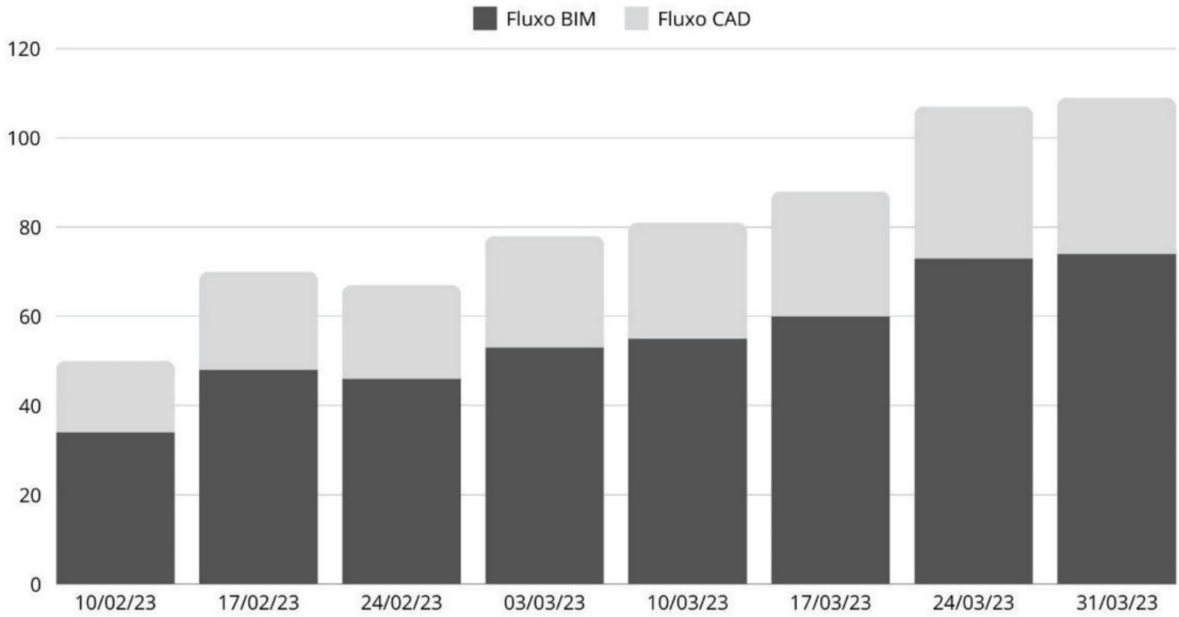

Figure 5: WIP x Throughput ratio
Source: The authors (2023)

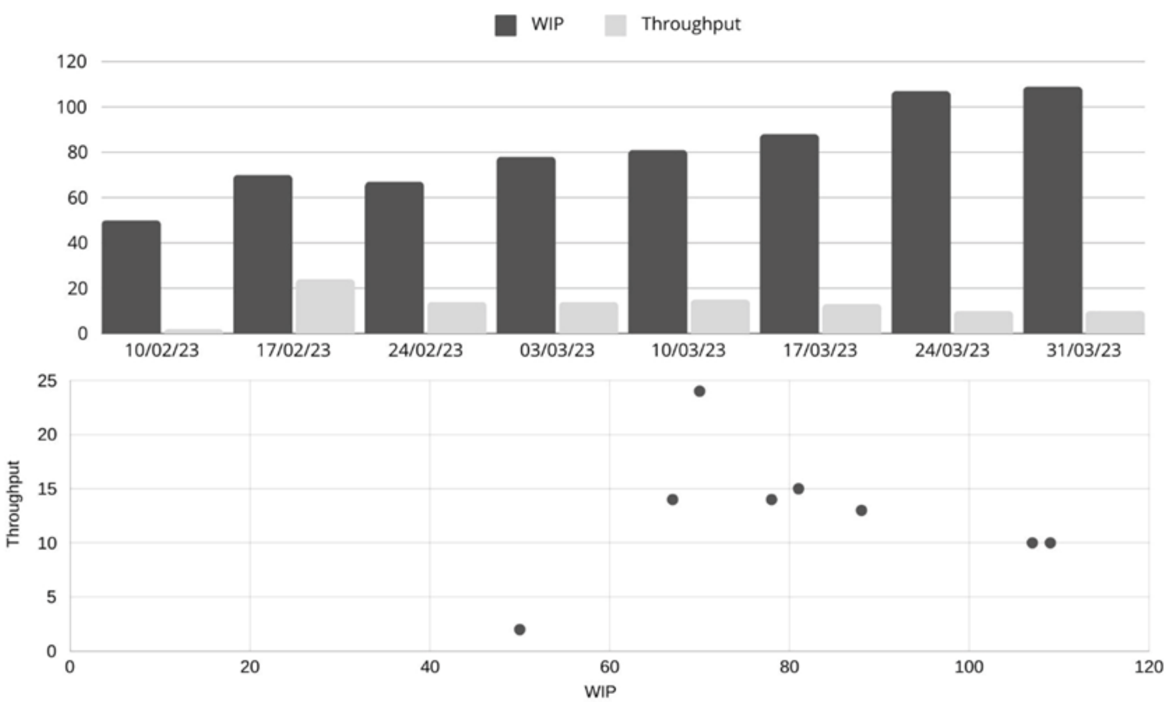

Figure6 : Work in Progress (WIP)
Source: The authors (2023)

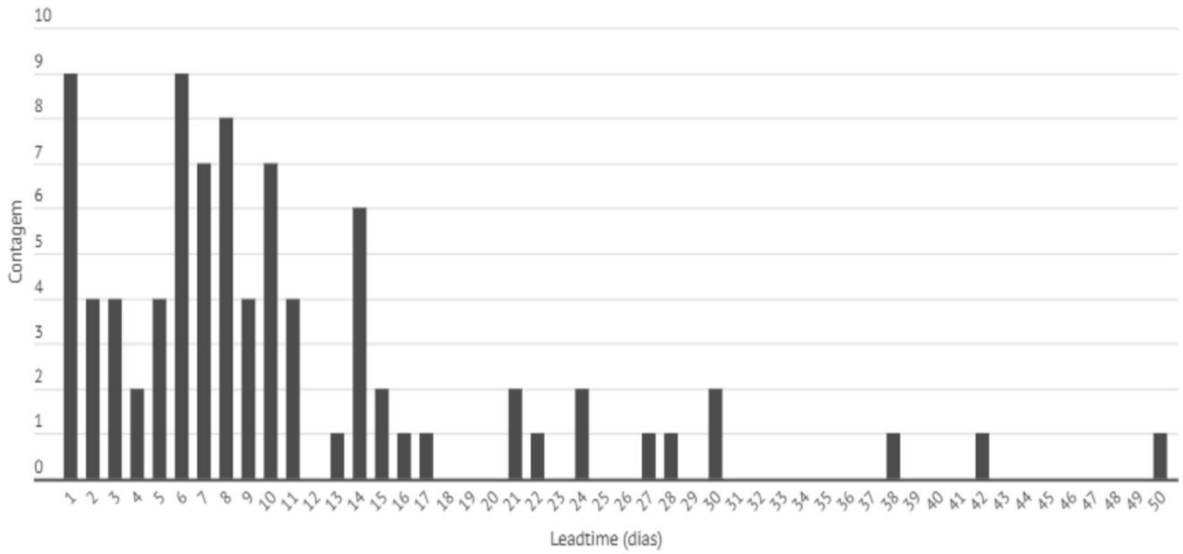

Figure7: Lead time histogram
Source: The authors (2023)

Figure8 : Percentage of failures
Source: The authors (2023)

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ADVANTAGES AND CHALLENGES OF IMPLEMENTING BIM

Although the advantages of using BIM are well known, issues such as quality and metrics are underdeveloped when applied to the system [20]. The most widely used metrics in the BIM environment are found in the architectural phase of the project (61%), followed by Engineering (22%) and Construction (17%), with an emphasis on theorizing, organizational benchmarking and productivity focused on architectural design [20]. As BIM is known as a collaborative process [2,3], it is important to measure performance across all design disciplines, including structural design.

The literature review identified that the implementation of BIM faces challenges related to organizational and process change [9], difficulties in making it compatible with contractors' schedules [8], a lack of structuring of processes, information flows and protocols [2] and a low level of maturity of network technologies and software [9].

In the company studied, the BIM flow has advantages when it comes to revisions and estimates, since it has much greater automation, which makes revisions faster and more assertive. When a revision is made to the model, the plans, sections and quantities that make up the 2D documentation are already changed automatically. The calculation of quantities in the BIM flow is also done automatically. On the other hand, each project revision in the CAD flow requires a revision of dimensions, quantities, levels and nomenclatures.

However, two main difficulties were identified in relation to the implementation of BIM: a high number of revisions and failure to meet the client's deadlines. With regard to the high number of revisions, the following were identified as possible causes: lack of communication between the parties involved in the project, lack of definition of the deliverables, low maturity of the BIM models in the initial phases, saturation of the WIP, lack of control procedures and lack of training for employees in the use of BIM.

With regard to failure to meet deadlines, the following possible causes were identified: lack of communication between the parties involved in the project, saturation of the WIP, lack of resources to serve the client, bottlenecks in the process, poorly defined work items, changes in the scope of an item during development and lack of training for employees in the use of BIM.

PROPOSALS FOR IMPROVEMENT

Based on the difficulties encountered, some suggestions for improving the BIM flow were proposed. The proposal defined three levels of improvement: strategy, production and flow management. At the strategy level, it was suggested that the scope and deliverables be aligned with the client and that the BIM team be increased by at least 20%, through training and capacity building.

With regard to production, it has been suggested that the hybrid process (2D and 3D) be gradually reduced by adopting frequent work routines through plug-ins. These routines facilitate frame detailing, which is still done in 2D [21]. Another issue proposed was to modify the infrastructure modeling work stage, which used to be modeled twice, once by the engineer and once by the designer responsible for the 3D model that was delivered to the client.

To manage the flow, we suggested implementing the agile *Kanban framework*. We understand the difficulty of sudden changes in organizational culture, professionals and project processes [9,10]. Because of this, *Kanban* would be a smoother way to make this transition [13].

With regard to the analysis of the metrics, it was suggested that the WIP of the system's main bottlenecks "Awaiting Development", "Awaiting Audit" and "Awaiting Delivery" be limited. It is understood that limiting the WIP of all stages can radically alter many variables at the same time, and the ideal is to start by setting limits for the most critical stages [13]. Limiting WIP can bring some advantages, such as: preventing bottlenecks from forming, helping to reveal system blockages to all the agents involved, increasing the quality of the product delivered and reducing errors and rework [13].

Agile management techniques associated with BIM result in a multidisciplinary coordination structure, with a reduction in rework and unnecessary effort resulting from a lack of communication and inefficient sequencing of tasks [15]. Agile methods encourage inspection and continuous improvement [22], so working with metrics in a *feedback* loop in parallel with the development flow can guarantee better decisions for the team and help improve communication throughout the organization.

RESULTS OF IMPLEMENTING IMPROVEMENTS

Some of the suggested improvements have been implemented over the last year. These include aligning the scope and deliverables with the client before the start of the project, managing and training the teams, monitoring production using agile metrics and using the *Kanban* board.

After implementing the suggested improvements, a series of positive results were observed. One year after adopting the changes, the company recorded a 60% reduction in the number of failed measurements sent to clients (Figure6). This result was related to the alignment of scope and deliverables with the client before the start of the project and the management and training of the teams.

Another positive result was a 30% increase in the company's average turnover. This growth was attributed to greater efficiency in project delivery and a reduction in rework, which freed up more resources for the company to handle a greater number of contracts.

CONCLUSION

The study highlighted the impact of adopting BIM on the workflow of a structural design company, analyzing the process based on three agile metrics: *Work in Progress (WIP), Lead Time* and *Throughput*. Although BIM has brought significant benefits, such as the automation of revisions and quantities, two main difficulties were identified: a high number of revisions and failure to meet the client's deadline

Analysis of the metrics made it possible to identify bottlenecks in the workflow and propose strategic, production and management improvements. Among the suggested actions were aligning deliverables with clients at the start of the project, managing and training the team and monitoring production using agile metrics and a *Kanban* board.

A year after applying these measures, the results were positive: the company reduced the number of rejected measurements sent to clients by 60% and increased its average turnover by 30%, showing that the combination of BIM and agile methodologies can significantly optimize the productivity and quality of projects.

One of the limitations of this research was not considering the size and difficulty of the tasks involved in the process. The analysis focused exclusively on the division of activities by type of deliverable, without taking into account the complexity or effort required to complete each task. This approach may have limited the accuracy of the results, especially in projects where variability in task difficulty can significantly impact the time and resources required. It is recommended that future research incorporate a more detailed analysis of task complexity to improve the evaluation of process efficiency.

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