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AN AGILE APPROACH TO IMPLEMENTING THE PRINCIPLES FOR FLOW DESIGN AND IMPROVEMENT: A CASE STUDY IN A MINING PROJECT

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ABSTRACT

This study addresses the challenges in the construction industry by implementing Scrum, an Agile methodology, to apply Koskela's Principles for Flow Design and Improvement in a mining EPCM project. The research identifies a gap in integrating these principles into comprehensive project management. A case study was conducted in Arequipa, Peru, focusing on the installation of an underground primary crushing station and its associated conveyor system. The project was led by the owner's project team, who are also the authors of this paper. The study employed a mixed-methods approach, combining quantitative and qualitative data to enhance the validity and reliability of the results. Cronbach's Alpha was used to measure the internal consistency of the survey instrument. The study was applied during the engineering and procurement stages. Survey results indicated a positive perception of Scrum's impact, with high internal consistency across various constructs of Koskela's Principles for Flow Design and Improvement. Key findings include enhanced collaboration, transparency, and continuous improvement. Additionally, there was a 7.3% increase in Percent Plan Complete (PPC) over 33 weeks, demonstrating improved team adherence to weekly plan commitments. These results suggest that Scrum is a powerful tool for transforming construction project management.

KEYWORDS

Lean construction, Scrum, Agil, Last Planner, Flow Design.

INTRODUCTION

The construction industry faces numerous challenges, including high variability in processes, non-value-adding activities, and a lack of alignment with customer requirements (Koskela, 1992). To address these issues, Koskela formulated the Principles for Flow Design and Improvement, which have significantly impacted both academia and industry, driving new research lines, fostering collaboration between the two sectors, and inspiring professionals to seek innovative ways to manage projects.

Despite improvement efforts primarily focusing on the construction phase, it is necessary to explore deeper integration of these principles into comprehensive project management. The Lean Project Delivery System (LPDS), introduced by Ballard in 2000, aims to maximize customer value and minimize waste throughout the project lifecycle. However, incorporating new tools and approaches, such as Agile methodologies, can further enhance efficiency and effectiveness in project management.

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Research on the applicability of Agile management in construction projects is limited but growing. Streule et al. (2016) found that implementing Scrum in the design phase of a construction project in Switzerland significantly improved transparency, communication, and collaboration within the team. Power, Sinnott, and Lynch (2022) reported an 11% increase in average Percent Plan Complete (PPC) with the application of a combination of Scrum and LPS in the expansion of a warehouse in Ireland. Jethva and Skibniewski (2022) highlighted the benefits of Scrum in a school construction project in Washington, D.C., allowing the project to be completed on time and within budget. In the construction of a residential complex, Power et al. (2024) found that the combination of LPS, Takt, and Scrum resulted in a 21% increase in average PPC, improving productivity and schedule adherence.

The objective of this study is to explore the application of Scrum, an Agile methodology, in a mining project in Peru, to evaluate its impact on the implementation of the Principles for Flow Design and Improvement proposed by Koskela (1992). The study aims to demonstrate how Scrum can enhance efficiency and effectiveness in construction project management, particularly in the engineering and procurement stages, and how it can foster a culture of collaboration, transparency, and continuous improvement.

LITERATURE REVIEW

For this research, the Principles for Flow Design and Improvement formulated by Koskela (1992) were chosen as the foundation due to their relevance and applicability in enhancing construction project management. These principles, derived from Lean literature, provide a robust theoretical framework for addressing inefficiencies and improving performance in construction projects. The seven principles chosen for this study—collaboration and communication, systematic consideration of customer requirements, reduce variability, increase output flexibility, increase process transparency, focus control on the complete process, and build continuous improvement into the process—were selected due to their comprehensive coverage of critical aspects in integral project management. By integrating these principles with agile methodologies such as Scrum, this research aims to demonstrate, through a case study, how efficiency and effectiveness can be improved fostering a culture of collaboration, transparency and continuous improvement.

COLLABORATION AND COMMUNICATION

Collaboration is a process that requires the participation and integration of different stakeholders, promoting a sense of involvement and ownership (Amaro et al., 2024). Although not explicitly included in the Principles for Flow Design and Improvement, collaboration and communication are essential in construction projects as they ensure efficient coordination among all stakeholders and maintain a professional and committed work environment. Additionally, keeping the client informed and involved in all phases of the project ensures that their needs and requirements are met, enhancing their satisfaction and trust.

The Agile methodology enhances communication and collaboration through Scrum ceremonies, keeping the team aligned and informed about progress. It fosters a collaborative environment, provides real-time project visibility with tools like Kanban boards, and facilitates continuous feedback through retrospectives. Additionally, it breaks down silos, ensuring everyone works together towards the project's goals and the client's expectations. According to the Agile Manifesto, individuals and interactions are valued over processes and tools, emphasizing the importance of people and their effective collaboration (Beck et al., 2001).

SYSTEMATIC CONSIDERATION OF CUSTOMER REQUIREMENTS

The core of Lean and Agile culture is the customer. Koskela (1992) urges identifying customers for each stage and considering their requirements throughout the project as a key factor for value generation. In 2000, Koskela proposes a value-centered production vision, where customers are the main focus, as only they can define what is valuable. Additionally, the theory of value generation emphasizes collaboration with suppliers to ensure quality and identify the needs of internal customers when designing the production system (Liker, 1996).

In practice, for organizations, projects are fundamental as they enable the implementation of strategic changes, process improvements, development of new products or services, and achievement of specific objectives that contribute to growth and competitiveness (Project Management Institute, 2017). This approach requires close collaboration between the project team and the internal customer to meet strategic objectives. Stakeholders must integrate and align in a common language to capture operational needs, define requirements and ensure continuous follow-up throughout the project.

The Agile methodology, introduced in the early 2000s, addresses the shortcomings of traditional approaches, such as the waterfall methodology, which were more rigid and less adaptable to rapid changes and customer needs. Since then, the Agile methodology has been widely adopted in software development and other fields due to its flexibility, customer-centric focus, and continuous improvement.

REDUCE VARIABILITY

Variability in construction processes often leads to disruptions, delays, and increased costs. According to Shaikh et al. (2020), the most common causes of claims in construction include incomplete designs, inadequate specifications and drawings, change orders, delays in decision-making, delays in the delivery of drawings and specifications, and site conditions. The predominant approach to avoid these claims is to draft a contract that protects the owner from the consequences of deficiencies and uncertainties in the contract documents (drawings, specifications, scope, site conditions, etc.), transferring the risk to the contractor. However, this strategy does not always work because the risk does not disappear, uncertainty and variability persist, and sooner or later, problems arise and cause disruptions in the construction process.

Ballard and Howell (1997) proposed that shielding construction and stabilizing workflow using the Last Planner System (LPS) methodology is a solution to reduce uncertainty. However, advances in literature and iterative research highlight shortcomings in relying solely on the LPS as the production planning and control methodology of Lean Construction (Power et al., 2024). Identified gaps included a lack of proactive efforts in analyzing delays, implementing changes, and managing contracts (Olivieri et al., 2019) and an incomplete constraints closeout process (Power et al., 2021, as cited in Power et al., 2024).

Managing variability involves a multi-organizational process that includes the owner, project team, client, designer, contractor, supplier, consultant, and others. It is also a multi-phase process encompassing conceptualization, design, construction, and maintenance. Project management is a network of multiple stakeholders and relationships, involving the flow of information, materials, services, and products.

The integration of alternative project management methodologies such as Scrum seeks to complement the shortcomings of the Last Planner by improving the reliability of planning and reducing variability. The values of the Agile Manifesto are essential in this management approach. These values emphasize communication and collaboration among individuals over strictly adhering to specific processes and tools. They prioritize having a functional solution over exhaustive documentation, promote continuous collaboration with the client rather than focusing solely on contractual terms, and favor the ability to adapt to changes and respond quickly over following a rigid, predetermined plan (Beck et al., 2001).

INCREASE OUTPUT FLEXIBILITY

The MacLeamy curve (Ilozor & Kelly, 2012) illustrates how the effort and cost of making changes in a project vary depending on the phase in which problems are identified. As the project progresses, the team's ability to influence key factors such as cost, schedule, and functionality decreases. Decisions made in the early stages have a greater positive impact, while the costs of making changes increase exponentially as the project advances. Consequently, modifications in advanced stages are much more expensive than those made in the initial stages. Under this perspective, impact evaluations are conducted by comparing the changes with the project's baseline (scope, cost, and schedule), often overlooking the strategic objectives that the project's execution represents for the organization.

On the other hand, the mining industry is continuously innovating through advanced technologies that enhance operational efficiency, safety, and sustainability. It is also highly sensitive to legal restrictions, requiring flexibility in project management to adapt to technological disruptions and legal mandates for successful implementation.

Although the required changes impact schedule, cost, and scope, they are essential to ensure that the final result meets the client's expectations and provides greater long-term value. From the owner project team's perspective, the successful implementation of changes showcases their capacity for innovation and competitiveness, enhances customer satisfaction, reinforces their reputation, and contributes to long-term optimization and efficiency, aligning with the organization's strategic objectives.

INCREASE PROCESS TRANSPARENCY

A lack of transparency in processes increases the likelihood of errors, reduces visibility, and diminishes the motivation to improve. Therefore, it is necessary to make the production process transparent and observable to facilitate better control and continuous improvement. Make the main flow of operations, from start to finish, visible and understandable to all employees (Stalk & Hout, 1989 referenced in Koskela 1992). This can be achieved by making the process directly observable through physical or organizational means, measurements, and public display of information (Koskela 1992).

Kanban in Scrum improves process transparency by providing a clear visualization of work through boards that show the status of each task in real-time. This facilitates the identification of bottlenecks, constraints, and improves the understanding of workflow. By limiting work in progress (WIP), Kanban helps teams focus on completing tasks before starting new ones, making progress more predictable and visible to everyone. The constant visualization of work promotes open and continuous communication among team members, allowing everyone to see which tasks are in progress, which are blocked, and which have been completed. Additionally, each team member can see who is working on what task and at what stage it is, fostering shared responsibility and collaboration.

FOCUS CONTROL ON THE COMPLETE PROCESS

Koskela (1992) suggested that to avoid suboptimization caused by segmented flow control in organizations, the entire process should be measured, and a control authority should be established by appointing cross-functional process owners. He also proposed a more radical alternative: allowing self-directed teams to manage their own processes. Scrum helps solve the problem of segmented flow control by forming self-managed, cross-functional teams that work together in all phases of the project, reducing the need to transfer work between different specialties. The Product Owner manages and prioritizes tasks, ensuring that the team focuses on high-value activities. Daily meetings allow for quick identification and resolution of problems while improving coordination and collaboration, and sprint reviews facilitate communication between multiple teams in large projects, ensuring everyone works towards common goals and resolving inter-organizational issues.

De Smet (2018) illustrated how agile organizations combine stability and dynamism to quickly adapt to changes and opportunities. This agile model is represented as a network of autonomous and empowered teams operating within a culture centered on trust in people. Managers in agile organizations support teams by providing resources and direction rather than supervising daily tasks. Similarly, Bertelsen (2017) argued that in complex projects, detailed vertical control is beyond our capabilities. As leaders, we can only foster trust, disseminate information, delegate responsibilities, and build upon that trust.

BUILD CONTINUOUS IMPROVEMENT INTO THE PROCESS

Koskela (1992) emphasizes the importance of continuous improvement in organizational processes, highlighting that it should be a constant and systematic activity. To institutionalize this improvement, progress must be measured and monitored, ambitious goals that reveal problems and foster solutions should be set, and the responsibility for improvement should be assigned to all team members.

Scrum can be an effective tool for fostering continuous improvement in an organization, as it includes regular reviews and retrospectives at the end of each sprint to assess and monitor improvement. The Product Owner defines clear and ambitious goals for each sprint, helping to identify problems and stimulate innovative solutions. Scrum encourages self-organization and shared responsibility, motivating all team members to propose and test new ideas. It employs standard frameworks and ceremonies, such as daily meetings and retrospectives, which are constantly reviewed to find more efficient ways of working. Retrospectives aim to identify and address process limitations, eliminating the root causes of problems. Implementing Scrum helps institutionalize continuous improvement, ensuring that the organization reduces waste, increases value, and constantly adapts to emerging challenges and opportunities.

CASE STUDY

CASE PROJECT

The project is located in Arequipa, Peru, at an altitude of 2,780 m.a.s.l. The In Pit Crusher and Conveying Project (IPCC) involves installing an underground primary crushing station and its associated material handling system. The gyratory crushing station has a processing capacity of 160,000 tons per day. The material handling system includes a 2.5 km long conveyor.

Figure 1: IPCC Project General View

Due to the critical importance of time, a fast-track methodology was adopted. Close collaboration with the client (operations and maintenance) was maintained to identify and adequately address their requirements throughout the project's execution. Additionally, the need for flexibility and adaptability was recognized to ensure client involvement and satisfaction with the project's deliverables. Therefore, based on the project manager's previous experience with agile teams within the organization, it was decided to implement this methodology.

SCRUM IMPLEMENTATION

The Owner Project Management Office directly managed the entire project and was responsible for implementing the improvement processes detailed in this paper. Scrum was utilized during the detailed engineering, procurement, and early construction stages.

The Scrum team consisted of a project manager acting as the Product Owner (PO), a planning and control engineer serving as the Scrum Master (SM), and a development team comprising various specialists: a civil engineer for earthworks, a structural civil engineer, two mechanical engineers (one for conveyor systems and one for crushing), two electrical engineers (one for medium voltage transmission and one for medium and low voltage distribution), an instrumentation and control engineer, and two project control engineers. Each team member had the autonomy to determine how to approach their tasks and organize their work, leveraging their diverse and complementary skills. They worked together, sharing responsibility for the success of the sprint and the final product, which gave them a strong sense of ownership and commitment. They made decisions iteratively, with continuous adjustments based on feedback. Additionally, they maintained transparency in their processes and progress through daily meetings and sprint reviews, ensuring everyone was informed and aligned.

The main role of the PO was to maximize the project's value and support the Scrum team in achieving their goals. Additionally, the PO was responsible for creating, updating, and prioritizing the Product Backlog items (PBIs), ensuring they were clear, transparent, and understood by all. To accomplish this, the PO relied on the project's scope, the business case for funding approval, as well as recommendations from operability, maintainability, constructability, HAZOP workshops, and periodic meetings with end-user areas. This approach allowed the PO to consider the interests of other stakeholders and stay constantly updated with the organization's strategic objectives.

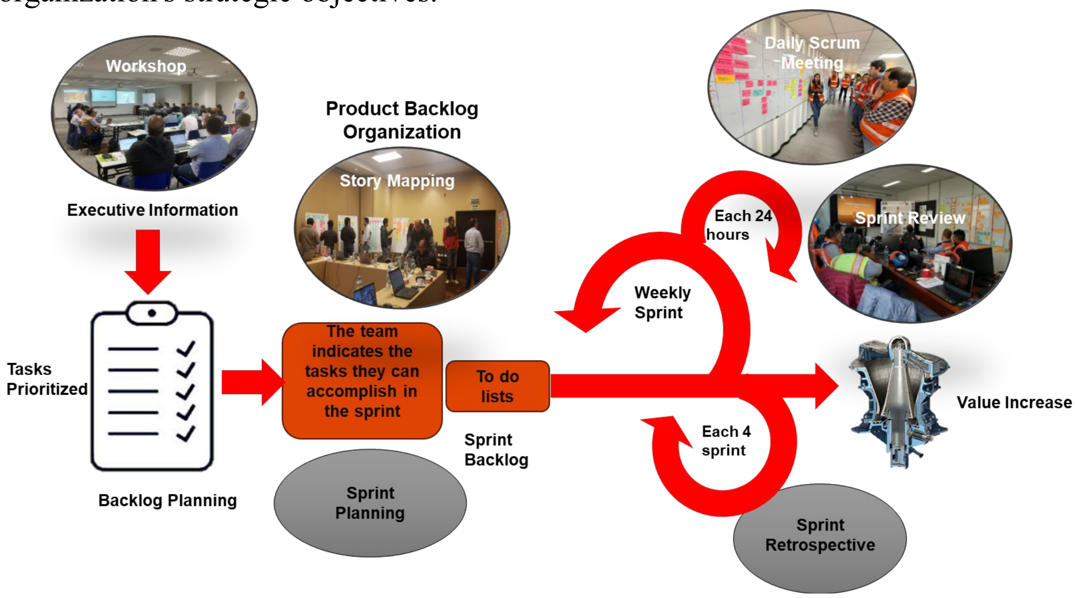

Figure 2: Scrum model for the IPCC project

For the study project, the Sprint duration was one week. The work to be done in the Sprint was planned in the Sprint Planning. This plan was created through the collaborative work of the team based on the prioritized PBIs according to the construction schedule, procurement plan, contracting plan, and execution plan. The Daily Stand Up was held every day at the start of the day for 15 minutes. In this event, the development team planned the work for the next 24 hours, shared progress, and, if required, requested help to complete tasks.

The Sprint Review, held at the end of each Sprint, involved stakeholders who reviewed progress, adjusted the Product Backlog, and collaborated on future steps. Given the close daily coordination between the PO and SM with the project team, Sprint Retrospectives were conducted monthly. These meetings provided a safe environment for the Scrum team to critically evaluate their processes, techniques, relationships, and interactions, and to plan improvements to enhance performance (Streule et al., 2016).

RESEARCH METHODOLOGY

The primary objective of the study was to evaluate how implementing Scrum facilitated the application of Koskela's Principles for Flow Design and Improvement (1992), and improved efficiency and effectiveness in managing construction projects.

The research methodology, designed and implemented by the project manager based on his experience with agile teams, employed a mixed-methods approach combining quantitative and qualitative data to enhance validity and reliability. It was based on a single-project case study design, applying action research principles.

The literature review examined how Koskela's (1992) Principles for Flow Design and Improvement enhance performance in construction projects. Additionally, it reviewed previous studies demonstrating how combining agile methodologies with Lean approaches improves plan adherence and productivity.

To assess the team's perception of the impact of Scrum implementation on the Principles for Flow Design and Improvement, a survey was designed and administered during the engineering, procurement, and early construction stages of the project. Fourteen participants, including the entire project management team and client representatives, responded to the survey during one of the Sprint Review meetings. The survey was structured into several sections: (a) demographics, gathering basic information about the respondents; (b) experience with agile methodologies, including questions about the team's knowledge or prior experience with agile methodologies; (c) constructs associated with the Principles, featuring 30 questions on a 5-point Likert scale ranging from strongly disagree to strongly agree, organized into themes such as collaboration and communication, customer focus, flexibility, transparency, integration, continuous improvement, and constraint management; and (d) open-ended questions addressing the suitability of Scrum for different project phases and the challenges of its implementation.

The collected data was entered into a database for quantitative and qualitative analysis, ensuring the confidentiality of the information provided by respondents. The internal consistency of the items was verified using Cronbach's alpha to ensure the reliability of the results. According to Gliem and Gliem (2003), when using Likert-type scales, calculating and reporting Cronbach's alpha is essential for the internal consistency reliability of any scale or subscale used. Cronbach's alpha measures the degree of correlation between a set of items as a group. George and Mallery (2003) offer the following interpretation: values above 0.9 are considered excellent, those above 0.8 are good, those above 0.7 are acceptable, those above 0.6 are questionable, those above 0.5 are poor, and those below 0.5 are unacceptable. Furthermore, Gliem and Gliem (2003) note that an alpha of 0.8 is probably a reasonable target.

To assess the project team's efficiency in fulfilling commitments, the weekly Percent Plan Complete (PPC) was used during the one-week sprints in the engineering development phase. Power and Taylor (2019), following Howell and Macomber's (2002) argument, establish that a

PPC value of 80% can be considered "good," while values below 60% are classified as "poor." On the other hand, teams with a high level of maturity can maintain daily PPC levels of 85%.

Finally, open-ended responses were reviewed to identify recurring patterns and themes, offering a deeper understanding of the team's perceptions and experiences with Scrum implementation. This qualitative analysis complemented the quantitative data, providing a richer and more detailed context regarding the perceived benefits and challenges.

FINDINGS

EFFICIENCY IN THE EXECUTION OF PLANNED TASKS

Figure 3 shows that during the implementation stage, from week 01 to week 04, an average PPC of 68.7% was achieved. As the Scrum process matured and was better understood, results showed an upward trend. In the following weeks, compliance exceeded 75%, and from week 19 onwards, it consistently remained above 80%. This indicates that the fulfillment of commitments improved in the weeks following the implementation of Scrum.

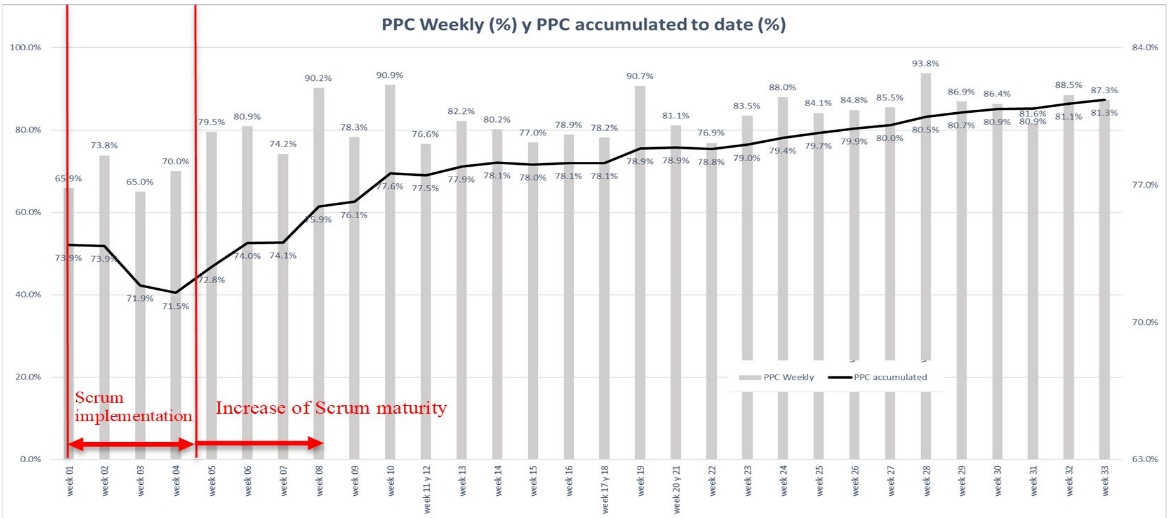

Figure 3: Evolution of PPC

Power et al. (2024) mention that none of the Lean studies reviewed achieved or sustained a PPC level above 80%, considered "mature," over the observation period. This disparity could suggest that consistently reaching and maintaining an 80% PPC is an exceptionally challenging goal. On the other hand, Power et al. (2010), citing Liu et al. (2010, p.240), state that "...PPC and productivity are positively correlated." This means that as PPC increases, productivity also rises. Therefore, the increase in PPC during the last 29 weeks (application of Scrum to the constraint management process) confirms higher productivity, directly resulting from a more focused and diligent process of identifying and resolving constraints.

PRINCIPLES FOR FLOW PROCESS DESIGN AND IMPROVEMENT

The survey results indicate a generally positive perception of the Scrum implementation across various constructs. "Increased collaboration and communication" received the highest average score (4.42) with a Cronbach's Alpha of 0.83, suggesting strong internal consistency and a very favorable perception in this area. "Continuous improvement" and "Reduction of variability" were also highly rated, with averages of 4.28 and 4.21 respectively, and Cronbach's Alphas of 0.72 and 0.71, reflecting lower internal consistency among the evaluated constructs. "Focusing control on the entire process" and "Increasing process transparency" received averages of 4.19 and 4.16, with Cronbach's Alphas of 0.83 and 0.83, suggesting strong internal consistency. Finally, "Consideration of customer requirements" and "Increased flexibility" received averages of 3.93 and 3.76, with Cronbach's Alphas of 0.76 and 0.80, respectively, indicating a moderately positive perception but with room for improvement, although with lower consistency in considering customer requirements.

Table 1: Results of Scrum Implementation Perceptions

Item	Dimension	Average	Cronbach's Alpha
1	Increase collaboration and communication	4.42	0.83
2	Consideration of customer requirements	3.93	0.76
3	Increase flexibility of results	3.76	0.80
4	Increased transparency of the process	4.16	0.86
5	Focus on complete Process control	4.19	0.83
6	Continuous improvement in the process	4.28	0.72
7	Variability reduction	4.21	0.71

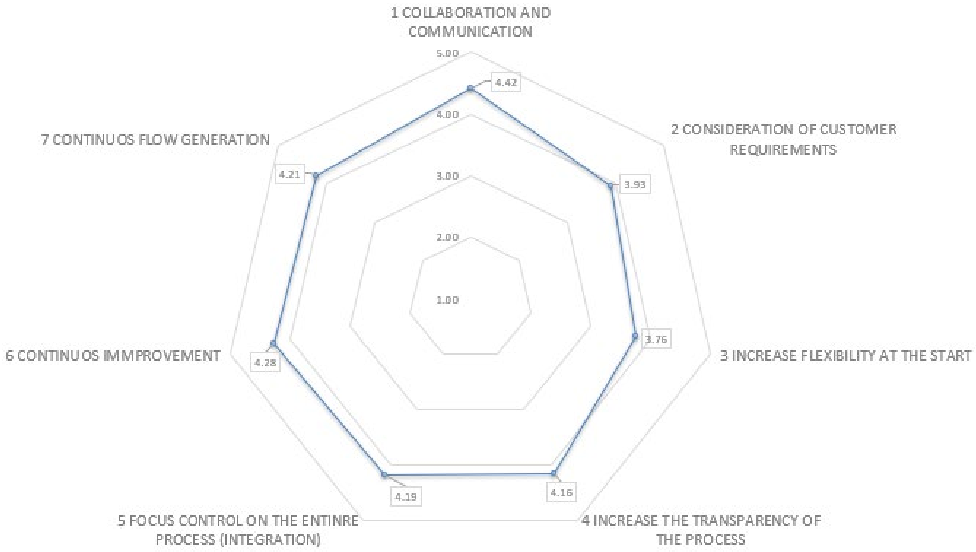

Figure 4: Project Team's Perceptions on Scrum Implementation Across Various Criteria.

In summary, the results indicate that respondents perceive the benefits of Scrum positively across all evaluated dimensions, with particular emphasis on collaboration and communication, process transparency, and continuous improvement. The internal consistencies (Cronbach's alpha) are generally good, suggesting that the questions within each dimension are coherent and reliably measure the corresponding constructs. However, there is room for improvement in the internal consistency of some dimensions, such as consideration of customer requirements and continuous improvement. Likewise, open questions highlighted the need for training in agile methodologies.

DISCUSSION

The implementation of Scrum in IPCC project, especially in the engineering and procurement stages, has proven to be highly beneficial, standing out in several areas of the Principles for Flow Design and Improvement. The team's perception of improved collaboration and communication is particularly notable, with high average survey scores and strong internal consistency. This suggests that Scrum facilitates better coordination and alignment among team members, which is essential for the success of complex projects.

Process transparency has also significantly improved thanks to the clear visualization of work through tools like Kanban boards. This transparency allows for early identification of bottlenecks and a better understanding of workflow, contributing to greater efficiency and productivity. Continuous improvement has been institutionalized through regular reviews and retrospectives, enabling the team to systematically identify and address process limitations.

While customer requirements and flexibility present areas for improvement, these dimensions were still positively evaluated. This suggests that with a more robust approach, even greater benefits can be achieved. It is necessary for Scrum teams to work closely with customers to ensure their needs and expectations are effectively met throughout the project.

In terms of efficiency, the increase PPC highlights the effectiveness of Scrum. The ability to maintain high PPC levels suggests that teams are consistently meeting their commitments, resulting in greater productivity and better management of time and resources.

On the other hand, the main challenges faced when implementing Scrum in the IPCC project were diverse. Firstly, there was confusion about the change in the management system, as the project team was accustomed to a hierarchical organization. When given the autonomy to plan and manage their own activities, they felt paralyzed, waiting for orders. Changing the mindset towards self-management took time. Additionally, some team members lacked the confidence to make decisions, which affected the team progress. Creating a trusting environment was also challenging, as team members were afraid to share their opinions and proposals for fear of being judged for their mistakes. Gradually, a safe environment was created that encouraged initiative and responsibility.

Coordination with other teams within the organization was another challenge. It is common for multiple teams to work together on EPCM projects, and a lack of coordination or overly rigid coordination following bureaucratic protocols could hinder the implementation of Scrum and project progress. A common factor in these challenges was the need to shape the team members' profiles to not only have technical skills but also a sense of empowerment, accountability, collaboration, adaptability, and team mindset. Fortunately, the Scrum methodology allowed team members to adopt and develop these attitudes, facilitating changes and the implementation of the Principles for Flow Design and Improvement.

CONCLUSIONS

The implementation of Scrum in the case project has proven to be an effective strategy for improving the management of fast-track construction projects by facilitating and promoting the application of Principles for Flow Design and Improvement proposed by Koskela (1992).

The specific contributions and benefits of implementing Scrum in project management were: a) it facilitated and promoted a culture of collaboration, transparency, and continuous improvement, allowing better coordination and alignment among team members; b) the implementation of tools such as Kanban boards improved process transparency, allowing for early identification of bottlenecks and a better understanding of workflow, which contributed to greater project efficiency and productivity; c) furthermore, regular reviews and retrospectives allowed the team to systematically identify and address process constraints, institutionalizing continuous improvement and ensuring that the project constantly adapted to emerging challenges and opportunities; d) likewise, although it was not deficient, with a more robust approach, even greater benefits could have been achieved in terms of considering client requirements and flexibility, ensuring that client needs and expectations were effectively met throughout the project, and e) on the other hand, Scrum implementation consistently increased and maintained high Plan Percentage Completeness (PPC) percentages, suggesting that teams consistently deliver on their commitments.

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