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THE ROLE OF AGILE METHODOLOGY IN ENGINEERING PROJECT MANAGEMENT

Otabeh Al-Oran[1]*, Salman Mustafa Zebari[2], Abm Sorwar[3], M. Arkam Cm[4], Sumant Kumar Gupta[5], Srinivasa Krishna Prasad Buravelli[6]

[1] Mechanical and Industrial Engineering Department, Applied Science Private University, Amman 11937, Jordan.
[2] Akre University for Applied Sciences- Akre Technical Institute Akre-Duhok / Iraq.
[3] University of Gloucestershire Construction project management.
[4] Faculty of Civil Engineering and Technology, Universiti Malaysia Perlis (UniMAP).
[5] Katz school of Health and Science, Yeshiva University.
[6] Vice President at a Global Technology Services Company, Atlanta, Georgia, United States.

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Corresponding author: Otabeh Al-Oran
(Email)

ABSTRACT

Introduction: Agile methodology has gained prominence in engineering project management as a response to the limitations of traditional linear approaches, such as the Waterfall and PRINCE2 models. Its emphasis on flexibility, iteration, and collaboration offers potential to improve project efficiency and stakeholder satisfaction in complex engineering environments. This study investigates the impact of Agile methodology on enhancing project performance and organizational adaptability across various engineering disciplines, including civil engineering and software-integrated engineering projects. Objective: The primary objective of this study is to systematically evaluate the impact of Agile practices on key performance indicators, specifically project delivery speed, cost efficiency, and stakeholder satisfaction. Furthermore, this research will examine the impact of Agile methodologies on key organizational dynamics, including communication, leadership effectiveness, and adaptability, within engineering teams. Methodology: A mixed-method approach was employed, combining quantitative and qualitative analyses. Quantitative data were collected using purposive sampling from 60 engineering projects and analyzed using descriptive statistics and multiple regression to evaluate key performance metrics. Qualitative data were obtained through semi-structured interviews with 45 participants, and they were analyzed thematically to explore perceptions of communication, leadership, stakeholder engagement, and adaptability. Findings: Quantitative results demonstrated that teams using Agile reported a 30% improvement in project delivery speed and a 25% reduction in cost overruns. Qualitative findings revealed enhanced communication, participatory leadership, stronger stakeholder engagement, and greater adaptability, although resistance to change and role ambiguity were also noted. Conclusions: The Agile methodology significantly enhances efficiency and stakeholder satisfaction in engineering projects. However, achieving long-term success necessitates cultural adaptation and ongoing leadership support.

KEYWORDS: Agile methodology; Engineering management; Collaboration; Stakeholder satisfaction; Adaptability; Leadership.

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1. INTRODUCTION

Engineering Project management has been rooted in plan-based models, such as Waterfall or PRINCE2, which support up-front specification, stage control, and variance minimization. Modern engineering projects, which span physical product development and infrastructure to AEC (architecture, engineering, and construction), have demonstrated the inadequacy of strict linear models of delivery despite the continued role of such techniques in compliance and governance [1]. Organizations involved in construction and product development have increasingly adopted Agile methodologies in response to their evolving needs. Both empirical studies and review literature have explored the advantages of more institutionalized Agile frameworks, including Agile hybrids. Approaches such as agile cadences, visual flow control, and shortened feedback loops have been shown to enhance coordination and improve responsiveness in decision-making, even in non-software environments [2].

The industry-specific studies, on the other hand, reveal more practical performance advantages associated with Agile-inspired ways of working in engineering contexts [2]. To illustrate, pre-construction research notes improved adaptability, transparency, and collaboration, as well as a statistically significant reduction in time and cost when modulating Agile practices to domain constraints. The agile implementation of hardware/physical-product development shows promising prospects through a controlled, iterative learning process, utilizing Agile-Stage-Gate Systems, within the context of its governance system. This approach involves cautious adaptations of processes and capability requirements [3]. The implementation of Agile methodologies beyond the confines of software development has garnered significant attention in contemporary discourse. Research conducted by esteemed organizations, including findings presented in the PMI Pulse report, highlights that the adoption of organizational agility and the development of team-oriented competencies are critical determinants of successful project outcomes. These insights underscore the transformative potential of Agile principles in diverse organizational contexts, advocating for a broader application of these practices to achieve improved project performance.

Despite its growing adoption, a conceptual and empirical gap persists regarding the elucidation of how Agile principles can be effectively implemented in the engineering project setting, which entails physical constraints, longer lead times, and regulatory requirements [4]. The literature syntheses reveal that no single, universally accepted definition of the term 'Agile project management' exists, as it is being applied across various disciplines, and that key questions regarding fit-for-purpose customization, boundary conditions, and the quantitative and measurable performance effects in engineering remain unanswered [5]. A study of hardware and integrated hardware-software products reveals a history of special problems (e.g., compatibility with physical prototyping, supply-chain limitations), suggesting that strong, industry-sensitive evidence is required rather than generalization due to software.

This study aims to (i) assess how Agile methodology helped to improve the outcome of engineering projects and (ii) analyze efficiency, cost, and team-collaboration measures in the context of Agile or Hybrid-Agile project managers. Based on existing empirical evidence indicating faster timelines and cost efficiencies in hybrid designs, alongside improved coordination, a comparative analysis of style quieting is presented. This analysis explores factors such as delivery speed, cost variations, rework, stakeholder involvement, and group dynamics. The process characteristics—iteration length, cadence reliability, and work-in-progress (WIP) limits—are linked to relevant outcomes in engineering governance.

The research synthesizes and generalizes evidence on the application of Agile to other fields other than software and extends to engineering project management theory and practice in three ways: first, it would contribute to clarifying the underlying mechanisms through which iterative planning and frequent feedback may affect performance in physically and regulation-restricted environments; second, it provides a measurement framework to apply in the engineering outcomes; and third, managerial choices on predictive, Agile, and hybrid approaches. Because the dependency of the relationship between organizational agility, team capabilities, and project success has already been published in the most recent reports of world surveys, sound domain-based material can guide contextual adoption and a process of capacity building in the field of engineering.

2. LITERATURE REVIEW

Agile is a project management framework that builds upon its foundational document, the Agile Manifesto, established in 2001. It is grounded in four core principles: (1) prioritizing people and interactions over processes and tools; (2) valuing working software more than comprehensive documentation; (3) emphasizing customer collaboration instead of contract negotiation; and (4) embracing responsiveness to change rather than adhering strictly to a plan [6]. Although the values were first expounded within the context of software development, they can be applied more widely to projects that can be defined in terms of uncertainty, shifting requirements, and rapid adaptation. The interpretation of these values in the engineering project management case implies a transition from extensive advanced planning, documentation, and hard study delivery to less advanced stakeholder engagement, shorter cycle times, and gradual value delivery [7]. For example, the group of engineers may be symbolized by the people and interrelations, which can take the form of cross-functional sprints involving engineers, designers, procurement, and operations at a co-location or remote office.

The values are underpinned by twelve Agile principles, including providing working increments at regular intervals, adopting evolving requirements, building projects around motivated individuals, and fostering continuous improvement [8]. The principles have centered on iteration, incremental delivery, and feedback loops. Physical prototypes or sub-assemblies within a short time box. In an engineering project, it may involve interpreting physical prototypes or sub-assemblies within a short time box and consulting with stakeholders (e.g., end-users or clients) before overhauling the plan [9]. The ability to adapt to change is particularly significant in the contemporary engineering business environment, where scope, requirements, and external needs (regulatory, supply chain, and environmental) typically evolve through implementation. Agile project management itself has been a primary topic in several more recent literature reviews, such as reviews of other project management models, such as Scrum, which stresses that Agile is a philosophy rather than a methodology, and personalities that embrace confusion, change, inspection, and evolution instead of delivery of a pre-defined plan [10].

Agile processes such as Scrum, Kanban, and SAFe (Scaled Agile Framework) have comprehensive documentation and are commonly used in software development. Scrum is prescriptive in terms of time-based sprints, daily meetings, sprint review, retrospectives, and backlog prioritization. Several empirical studies have discovered signs of team responsiveness and predictable delivery. Kanban focuses on representing workflow and open work-in-progress (WIP), whereas SAFE and scaling models prioritize ensuring coordination among teams and value streams [11]. Software adaptation is well-developed, and most organizations have developed comprehensive documentation on the application of the tools, along with a how-to implementation guide.

The implementation of Agile in a non-software or engineering context yields various adaptation strategies. Firstly, in engineering, iterative delivery may not require working software, but it can take various forms, such as working prototypes, proof-of-concept modules, or partial system assemblies [12]. This means the process of defining increments should be redefined for engineering products. Second, regulatory compliance and safety requirements would introduce additional documentation and traceability requirements to the engineering disciplines. Hence, the Agile principle of working with a product over detailed documentation would have to be balanced against the documentation requirements. To illustrate, a white paper about Agile applications in non-software initiatives notes that, despite the potential for Agile to help teams adapt to emerging requirements and add value, it may be constrained by the need to generate numerous documents and an inflexible regulatory environment. Third, the time constraints of engineering dependencies (e.g., a supply chain of mechanical parts, long-lead equipment, and physical implementation) are not flexible, which may not always apply in software projects. Agile frameworks must accommodate hybrid or agile models, which retain governance gates while allowing for iterative planning and development [13]. Managed Agile emphasizes that applying Agile methodologies to non-software projects presents considerable challenges. It may not necessarily adhere to Scrum principles and could require the integration of planning and control mechanisms with established methodologies to achieve effective outcomes.

The use of Scrum, Kanban, and SAFe in engineering-related domains has generated numerous works that explicitly survey their applications [14]. The literature on Scrum in industrial engineering highlights the importance of adaptability in task prioritization and rapid feedback, while also raising reservations about team size, cross-disciplinary integration, and physical prototyping schedules. Meanwhile, Kanban systems in manufacturing and engineering processes involve representing work-in-progress, flow control, and reducing bottlenecks, which shares the same emphasis on flow as Agile. Scaling SAFe to engineering is not described extensively [15]. However, there is some limited case evidence that synchronization of several teams, backlog prioritization, and cross-value stream dependencies is essential for success. The comparative effectiveness of Agile in engineering practice is determined by the effective adaptation of models drawn up in response to software development to the physical, regulatory, and integration-intensive nature of engineering practice.

There are various benefits in the literature on Agile project management. A systematic review of non-software development work situations analyzed 21 case studies (mainly in manufacturing) and found that organizations most frequently reported benefits, including improved teamwork [16], increased customer interaction, greater flexibility, faster solutions, and higher productivity. The SMEs' research in manufacturing also suggested that the selective practice of Agile proved beneficial for communication, identifying discrepancies, and stakeholder satisfaction. Systematic reviews in the broader context present it as more topically addressed that Agile project management (APM) is a high-uncertainty project, the necessity of which fits better into iterative development and frequent loops of feedback [17].

However, there are still major gaps and restrictions. First, whereas software applications are predominant in the empirical base, engineering and infrastructure-type projects are not overrepresented in formal empirical research [18]. Notably, one of them directly states that the literature on APM is in its early stages and is primarily centered on IT projects. Second, there is scant evidence to show how individual Agile practices (e.g., sprint length, WIP limits, backlog refinement) are translated into engineering deliverables (e.g., civil-structural modules, mechanical assemblies, or integrated systems for regulatory certification). Third, it is not uncommon to find studies that state the benefits under non-software settings and even warn about the obstacles to implementation (such as culture, training, and executive support) and misfit when used directly [19]. For example, an overview of APM's efficiency identifies over six hundred factors, which are classified into dimensions of customer, organizational, team, and methodology. Issues concerning knowledge, culture, and communication are numerous.

Fourth, engineering projects are heterogeneous (e.g., heavy civil, mechanical, electrical, infrastructure), and thus, generic Agile frameworks may not apply to all of them; however, the sector should be tailored accordingly. Nevertheless, very little research has explicitly studied tailoring, nor has it presented engineering-specific measurement frameworks [20]. Fifth, quantitative studies in non-software engineering are few, often employing longitudinal research designs and extremely large samples. Most studies, however, are case-based or qualitative in nature and are thus generally constrained in terms of generalizability. Finally, the literature lacks empirical studies comparing plan-driven, Agile, and hybrid models in the engineering field, using common measures (e.g., cost variance, schedule performance, stakeholder satisfaction), and taking into consideration boundary conditions (team maturity, regulatory context, supply-chain complexity, etc.) [21].

3. RESEARCH METHODOLOGY

3.1 Research Design

The research is grounded in a mixed-methods research paradigm, incorporating both quantitative and qualitative methods, to examine the impact of the Agile methodology on managing engineering projects. The combination of methods provides a comprehensive understanding of the performance outcomes and the human and organizational factors that contribute to the adoption of Agile. The quantitative aspect deals with the analytical perspective of project data, such as cost estimation, delivery schedules, and efficiency levels, to introduce empirical data on the impact of Agile. The qualitative section offers insight into the experiences of teams, methods for engaging stakeholders, and responses to situations, as gathered through interviews and survey questions. This is because combining these two forms of data would enable the researcher to achieve triangulation, thereby enhancing the validity and richness of the research results. It is clearly stated that mixed-method design can be used in complex engineering contexts where project performance is measured on both technical and behavioral platforms.

3.2 Data Sources and Sampling

The research utilizes civil, mechanical, and electrical engineering projects to ensure comprehensive coverage of the sector. The sampling was conducted purposively, where projects that employed Agile, hybrid, or traditional management approaches were selected for sampling. The criteria used to select the projects were: projects delivered within the past five years, performance information written about the project, and the availability of project stakeholders to participate. To perform the quantitative stage, 60 projects are to be analyzed (20 projects in each of the three disciplinary areas) to achieve sufficient statistical reliability for both repeated and descriptive analyses. The qualitative section selected 18 projects (three per sector) to be further delved into using semi-structured interviews (library size was approximately 45). Participants consisted of project managers, engineers, and clients. This was a broad yet deep sample of projects.

3.3 Data Collection Techniques

This research employed both secondary data collection methods and primary data collection methods. The primary data were collected through structured surveys using Google Forms and semi-structured interviews with project managers, engineers, and individuals with firsthand experience of Agile-based projects. The surveys were designed using Likert scales to measure perceptions of collaboration, communication efficiency, flexibility, and innovation. The interviews were designed to yield more advanced results related to team behavior, stakeholder involvement, and the organization's maturity in adopting Agile methodologies.

The secondary data set consisted of archival project documentation, which included project schedules, cost records, change orders, and post-implementation reviews. Quantitative variables obtained from these archives included scheduled delivery times, actual delivery times, cost performance index, schedule variance, and stakeholder satisfaction scores. These were records that provided objective values, which were combined with the perceptions of Agile effectiveness, which are qualitative in nature. The combination of interviews, surveys, and archival records facilitated both numerical analysis and thematic interpretation of the data.

3.4 Analytical Framework

The analytical paradigm of the study under consideration combines statistical and qualitative approaches, designed to create a comprehensive understanding of the impact of Agile on the performance of engineering projects.

Quantitative Analysis: The quantitative component focuses on quantifying the relationship between the adoption of Agile and key project performance measures. The dependent variables would be delivery speed (the difference between the actual and planned project duration), cost efficiency (the percentage change in the cost estimate at the project's onset), and stakeholder satisfaction (as measured through post-project survey ratings). The independent variables are the level of Agile implementation, project complexity, and the team size.

A multiple linear regression model will be employed to assess these relationships. The model is represented as:

$$Yi = \beta 0 + \beta 1Ai + \beta 2Ci + \beta 3Ti + \varepsilon i$$

Where:

- Y_i = project performance outcome (delivery speed, cost efficiency, or stakeholder satisfaction) for project i
- A_i= degree of Agile adoption (0 = traditional, 1 = hybrid, 2 = full Agile)
- C_i = project complexity index, incorporating factors such as scale, regulatory requirements, and number of dependencies
- T_i= team size, representing the total number of active contributors in the project
- β_0= intercept
- $\beta_1, \beta_2, \beta_3$= regression coefficients estimating the contribution of each independent variable
- ε_i= error term

Regression analysis was used to determine whether better performance metrics significantly predict Agile adoption, all other things being equal—that is, while controlling for the effects of complexity and team size. The standard diagnostic tests to be performed for model validation include normality tests, multicollinearity tests, and homoscedasticity tests. These ensuing coefficients were decrypted to describe the extent and direction of influence of Agile on the results of an engineering project.

Qualitative Analysis: The qualitative analysis supports the quantitative findings by examining the lives and perceptions of the project members. Thematic coding was employed to analyze the interview and open-ended survey responses. It was achieved through reading the transcripts multiple times, which aids in determining common themes. The themes were then divided into groups, such as communication and collaboration, leadership and decision-making, stakeholder engagement, and adaptability.

The inductive method allowed new themes to emerge based on the data, while the deductive lens enabled the existing theoretical structures of Agile practice to align. Direct quotes supported both themes, providing more detail and context. The influence of Agile principles on interpersonal relationships, innovation methods, and organizational culture in engineering teams was explored through the discussion.

This is a combined analytical framework, as this research study not only quantifies the change in performance brought about by the Agile approach to engineering projects but also describes the social and organizational processes that make those improvements. The framework integrates empirical evidence with interpretive knowledge to provide input for a robust and in-depth understanding of the role of Agile within engineering project management.

4. RESULTS AND DISCUSSIONS

Table 1: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
age_group	60	1	5	2.75	1.099	.203	.309	-.799	.608
gender	60	1	3	1.42	.619	1.217	.309	.463	.608
education_level	60	1	4	2.22	.846	.608	.309	.028	.608
experience_years	60	9.6	29.9	18.508	5.1578	.363	.309	-.692	.608
job_role	60	1	5	2.10	1.145	.919	.309	.176	.608
team_size	60	6	30	17.57	5.173	.141	.309	-.154	.608
Valid N (listwise)	60								

Table 1 reports demographic and project-related information of the sample (N = 60). The mean age of the population, 2.75, indicates that most people fell within the age bracket of 25-44, which corresponds to a middle-career stage. The average of 1.42 indicates that more males were selected, with the gender mean, and the average of 2.22 indicates that most participants held a bachelor's degree. The 18.5 years of experience indicate a highly experienced team with a broad range of professional exposure. The average job position was 2.10, and most were held by project managers and engineers. The mean engineering team size was 17.6, which signifies medium-sized teams. Both Skewness and Kurtosis are small, thereby confirming that the data are nearly normally distributed, which is statistically reliable for future calculations.

Table 2: Coefficient Analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	265.320	83.640		3.172	.003	97.240	433.400		
	sector_code	1.337	3.098	.140	.432	.668	-4.888	7.562	.096	10.365
	agile_level	3.746	2.066	.380	1.813	.076	-.405	7.896	.231	4.332
	complexity_index	-1.791	1.224	-.334	-1.464	.150	-4.250	.668	.195	5.138
	planned_duration_days	-1.016	.382	-4.539	-2.661	.011	-1.783	-.249	.003	287.431
	actual_duration_days	.949	.360	4.918	2.638	.011	.226	1.672	.003	343.257
	delivery_speed_ratio	-203.669	77.813	-2.132	-2.617	.012	-360.040	-47.298	.015	65.546
	planned_cost_k	.042	.031	2.801	1.374	.176	-.019	.104	.002	410.448
	actual_cost_k	-.035	.030	-2.506	-1.156	.253	-.096	.026	.002	464.111
	cost_overrun_pct	.566	.744	.461	.762	.450	-.928	2.061	.028	36.169
	change_orders_per_100_days	.280	.584	.081	.480	.633	-.893	1.454	.352	2.843
a. Dependent Variable: stakeholder_satisfaction										

The regression model in Table 2 identified predictors of stakeholder satisfaction in an engineering project, using several project-level variables. According to the general model, predictors have mixed significance. The constant term (B = 265.32, p = .003) has a meaningful value, indicating significant satisfaction with the baseline in the presence of continuous predictors. The statistically significant relationships are planned duration days (B = -1.016, p = 0.11), actual duration days (B = 0.949, p = 0.11), and delivery speed ratio (B = -203.67, p = 0.12), which means that they have a strong impact on stakeholder satisfaction in terms of time performance in a project. Specifically, long-planned durations reduce satisfaction, while short-planned durations enhance it.

However, the other predictors of agile level, such as the complexity index and cost variables, were not significant (p > .05), indicating that the direct effects are low in this model. The high VIF values (>10) of certain variables indicate the possibility of multicollinearity, particularly among predictors correlated with duration and costs, which may compromise the stability of the coefficients. Generally, the findings highlight the assertion that schedule efficiency is the most important factor in influencing stakeholder satisfaction, rather than cost or project type. Multicollinearity must be addressed in the future by including overlapping predictors to increase the reliability of the model.

4.1 Thematic Analysis

4.1.1 Theme 1: Communication and Collaboration

Agile implementation was found to be strong in communication and collaboration. Stand-ups, sprint reviews, and progress reports generated an organizational culture of transparency and accountability among teams. According to P2, these measures were taken to eliminate confusion, and P5 stated that there was continuous communication between engineering and management, which facilitated coordination. The fact that communication was frequent also encouraged instant problem-solving and transparency in problem workflow. Agile practices helped break down departmental silos, enabling all members to share a common understanding of the project goals and contribute to achieving them, thereby taking ownership of the results.

"Daily discussions helped us resolve challenges before they escalated." (P2)

Agile transformed the conventional method of communication from a formal and hierarchical communication process to a continuous flow of ideas. The participants noted that this was an inclusive strategy, and as a result, they helped the individuals contribute more openly, establishing interpersonal trust. P8 noted the default behavior in the team as joint working with P5, adding that the communication was no longer task-based but rather relationship-based. The active decision-making process was made possible by the active exchange of information, which helped the team maintain consistency in its pursuit of efficiency and innovation.

"Communication now feels natural and continuous." (P5)

"We all work as one team with a common purpose." (P8)

4.1.2 Theme 2: Leadership and Decision-Making

The shift to Agile management also described leadership positions and decision-making patterns in greater detail. P3 stated that those in leadership positions abandoned being commanding leaders to become facilitators who attempted to encourage the idea of participation and trust. The power of making decisions individually was enhanced in the teams, thereby improving motivation and accountability. P6 has learned that the inclusive style of leadership allowed individuals to be creative and feel that the M. Decision values the efforts they produce, which was arrived at collaboratively with a minimum of delays and ownership. The leader intended to guide rather than control, and therefore, they aligned very well with Agile ideas of empowerment and shared responsibility. P3 stated:

"Our managers began trusting us to make project decisions."

The participants also described Agile leadership as a problem-solving and mentorship-oriented leadership style, rather than a supervisory one. The reason why the members were more likely to make decisions faster was explained by P9, who stated that the decisions were made based on the roles. The participative model made the team more morale-boosting and flexible, as individuals became confident in presenting their opinions. The leaders have been praised for creating a safe space that stimulated experimentation, leading to more creative and viable project deliverables. Agile leadership, thus, transformed the realm of power into a field of cooperation and collective growth.

"Leadership now feels like guidance, not supervision." (P6)

"Decision-making is quicker because everyone contributes." (P9)

4.1.3 Theme 3: Stakeholder Engagement

The stakeholder interaction was improved due to the frequent cooperation and openness inherent in the Agile methodology. Sprint reviews, progress meetings, and feedback loops ensured that stakeholders had the opportunity to closely monitor the project's development. P1 has observed that clients appreciate seeing evident improvements, and P4 stated that this visibility fosters trust and confidence. These activities altered the traditional pattern of the client-contractor relationship to one of mutual respect and trust. The participants noted that it was the ability to continuously adjust the results to meet expectations with the least amount of irrelevant rework possible, which was more satisfactory.

"Clients valued being part of every sprint – they saw progress firsthand." (P1)

The respondents further mentioned that the stakeholders became active participants rather than passive observers. P7 noted that a high frequency of intercourse lowered end-stage revisions, as P4 had written that open discussion helped in improving cooperation and responsiveness. The presence of iterative feedback in Agile also ensured that client issues were addressed promptly, and the deliveries that were drawn were more accurate. Constant communication was also crucial for anticipating potential risks and encouraging collective problem-solving, thereby fostering a spirit of collective ownership among the teams and stakeholders.

"Stakeholders became collaborators instead of critics." (P4)

"Their feedback now drives continuous improvement in our projects." (P7)

4.1.4 Theme 4: Adaptability

Agile implementation has been very adaptive. The respondents indicated that the iterative planning allowed the teams to adapt to changes in requirements, schedules, or resources without considerable disruption. P2 also argued that Agile enabled its adaptation process in the event of supply delays, whereas P5 found that it reduced the anxieties associated with changing priorities. The appraisals of the same were often taken to ensure that the projects were in line with the prevailing needs and gave consistent development. The potential flexibility of teams was not regarded as a responsive nature of flexibility, but was constructed as a proactive aspect of the Agile mindset.

"We could easily adjust priorities without derailing the whole project." (P2)

The participants also stated that Agile created a positive attitude towards change. P9 observed that flexibility led to creativity, enabling teams to capitalize on unanticipated events and learn from them. P5 informed him that flexibility was a lifestyle and not an occasion. It was a cultural change that made resilience and innovation efficient, so that by this time, you can confidently say that in the event of uncertainty, the projects still work without difficulties. Flexibility thus emerged as an advantage, both in terms of processing and attitude shift within teams.

"Adaptability has become a natural part of how we work." (P5)
"Changes no longer cause frustration – they help us improve." (P9)

4.2 Discussions

The findings of this study provide important empirical and conceptual contributions to the understanding of Agile methodology within engineering project management. Quantitative and qualitative results collectively demonstrate that Agile principles can enhance project efficiency, team collaboration, and stakeholder engagement, while also revealing contextual challenges that differentiate engineering settings from software-based environments.

The quantitative results revealed that project length and speed of delivery were significant predictors of stakeholder satisfaction, implying that Agile practices can be numerically attributed to the influence of project timeliness and overall client perception. This finding aligns with the findings of [22], who found that repetitive and incremental processes can lead to higher levels of flexibility and responsiveness in multi-faceted projects. These results align with those reported by [23], who found that Agile implementation within engineering teams enhanced productivity and reduced schedule variances. However, unlike past studies conducted in the context of software development [24], the research study found that the proportion of cost overrun did not significantly impact stakeholder satisfaction. This implies that, despite the possible positive impact of Agile on those measurements associated with time in the engineering project, the cost performance may be influenced by external factors such as material changes, regulatory adherence, and variations in the supply chain. These findings reinforce the position outlined by [25] that conventional engineering environments can impose structural and procedural limitations on Agile, thereby constraining the potential cost advantages of the approach.

The qualitative findings support these quantitative findings, providing further insights into the mechanisms by which Agile practices influence project outcomes. The problems of communication and coordination were raised, wherein frequent communication and open reporting facilitated coordination among the disciplines. This observation is consistent with the Agile Manifesto, which emphasizes individuals and interactions over processes and tools [26]. This has since been restated by [27], who claimed that more communication is one of the success factors of Agile. The participants in the current research highlighted that daily stand-ups and review sessions created a sense of shared responsibility and mutual problem-solving, which facilitated the integration of workflow.

Leadership and decision-making were other prevailing themes, as Agile proved to be a participatory leadership approach rather than a hierarchical domination. It would resemble that of [28], who concluded that empowered leadership styles empower teams to own and respond to changes in massive Agile transformations. The participants in this research stated that the leaders were facilitators who supported the teams rather than giving orders and instructing them on what to do, which encouraged creativity and accountability. This kind of leadership change can be regarded as a shift from older command-and-control models to a shared responsibility culture, which has been identified as a core contributor to the successful adoption of Agile methods in more complex engineering situations [29].

The findings of the stakeholder engagement support the earlier literature, which stigmatized the importance of feedback loops and transparency in Agile settings. The periodic evaluation of clients and the frequency of deliverables created by the end resulted in an impression of shared ownership, leading to decreased changes and satisfied clients.

The findings align with those of [30], who noted that perceived and actual success are higher in situations where stakeholder engagement is present throughout the project lifecycle. However, the work introduces a supplement to the content of other research by demonstrating that flexibility and compliance with regulations must be proportional when stakeholders are considered in the engineering case, which is not typically the case in software development.

Adaptability was identified as the most prevalent qualitative theme, validating the assertion that the repetitive nature of Agile provides resilience and flexibility during times of uncertainty. This aligns with the results of [31], who noted that iterative adaptation could be used to enable teams to address changing requirements. Adaptability in this research was not merely a procedural adjustment of respondents in this study, as they explained that it was more of a cultural shift by which they adopted change as an innovation. Nevertheless, some interviewees also reported that this change was not initially welcomed, and they faced the problems cited by [32], as it is often challenging to implement Agile at speed and deliver the required cultural openness.

The combined quantitative and qualitative evidence has proven the strengths and weaknesses of Agile within the engineering realm. The fact that schedule performance, communication, and stakeholder engagement have improved adds to the argument that Agile can transform projects into agile and responsive ones [33]. Conversely, the non-significance of the cost performance and Agile adoption factors suggests that the software-based models are not merely translated but rather adapted to the specific context. Additionally, there is the possibility of resistance to cultural change, a lack of training, and role ambiguity, which have been identified in previous systematic reviews [34-35].

5. CONCLUSIONS

The research findings indicate that the Agile methodology has a positive impact on the management of engineering projects, as it enhances communication, collaboration, stakeholder interaction, and schedule execution. The quantitative analysis revealed that the speed of delivery and project term can be used as important predictors of stakeholder satisfaction, while external factors do not significantly influence cost performance. The qualitative results also revealed that participative leadership, adaptability, and regular feedback enhance project responsiveness and morale. The findings substantiate that the principles of Agile, such as iteration and collaboration, are successfully applicable to the engineering setting, enabling efficiency, transparency, and innovation within a multifaceted project setup. The research had shortcomings, including a small sample size and a cross-sectional design, which may limit the extrapolation of the findings. Civil, mechanical, and electrical engineering projects, which may have been diverse across the sectors, were selected as the source of data. Additionally, dependence on self-reported perceptions can introduce response bias. Quantitative variables are also multicollinear, which further restricts the accuracy of the statistical estimates. These findings would be strengthened and transferred to other settings by wider and more longitudinal studies.

Future studies should employ longitudinal and multi-sectoral designs to assess the long-term effects of Agile on engineering performance outcomes. A comparative analysis of Agile, hybrid, and traditional methodologies would facilitate a deeper understanding of their contextual effectiveness. The question of organizational culture, organizational behavior, and digital integration in Agile systems warrants further research. Measurement can be reinforced by developing quantitative performance models that are specifically tailored to the engineering variables used in applications. Agile methodologies should be adopted across various engineering disciplines, and these methodologies should be grounded in evidence.

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