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IJISPM

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The mission of the IJISPM – International Journal of Information Systems and Project Management – is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

The journal serves academics, practitioners, chief information officers, project managers, consultants, and senior executives of organizations, establishing an effective communication channel between them.

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The journal content provides relevant information to researchers, practitioners, and organizations, and includes original qualitative or qualitative articles, as well as purely conceptual or theoretical articles. Due to the integrative and interdisciplinary nature of information systems and project management, the journal may publish articles from a number of other disciplines, including strategic management, psychology, organizational behavior, sociology, economics, among others. Articles are selected for publication based on their relevance, rigor, clarity, novelty, and contribution to further development and research.

Authors are encouraged to submit articles on information technology governance, information systems planning, information systems design and implementation, information technology outsourcing, project environment, project management life-cycle, project management knowledge areas, criteria and factors for success, social aspects, chief information officer role, chief information officer skills, project manager role, project manager skills, among others.

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EDITORIAL

It is our great pleasure to bring you the third issue of the 14th volume of IJISPM. This is a special issue of selected and extended papers from the International Research Workshop on IT Project Management (IRWITPM). In this issue, readers will find important contributions on software metrics, digital transformation, megaprojects, artificial intelligence in agile project management, and agile project management education.

Metrics champions: navigating challenges and driving change in software measurement program implementation

Nataliya Berbyuk Lindström, Yixin Zhang

Research has been focused on technical approaches, leaving the behavioral and organizational aspects of metrics implementation underexplored. This study addresses this gap by adopting a job crafting perspective to examine challenges in metrics program implementation and how champions perceive and shape their roles to mitigate them. Based on a qualitative case study, we show that many difficulties arise from "soft factors," including unclear or conflicting objectives, misaligned expectations across teams, and weak communication channels. Without a shared understanding of metrics and their use, stakeholders interpret results inconsistently, undermining decision-making and engagement. Metrics champions actively craft their roles to address these barriers, taking on responsibilities such as educator, interpreter, and evaluator of data and tools. They also act as bridge builders and conflict mitigators, fostering collaboration and easing tensions among diverse stakeholder groups. These tasks, cognitive, and relational forms of crafting interact, enabling champions to move from passive adopters of metrics to active agents shaping the effectiveness of metrics initiatives. By combining job crafting theory and championing, we offer a human-centered view of software metrics implementation and emphasize the need for training and organizational support.

Modularity, learning, and the mitigation of power-law distribution of delay in large-scale technological infrastructure delivery

Kornpong Mahitthiburin, Kim Normann Andersen

Megaprojects, despite their crucial role in infrastructure delivery, consistently underperform in terms of time, especially when integrating technological innovations. Their reliance on the quantum leap approach struggles because of the temporary nature of project organizations and their inability to transfer experience across endeavors, producing a power-law distribution of delivery delays in which extreme overruns become inevitable. Grounded in the perspectives of system interdependency and self-organized criticality, our results from computer simulation of 50,000 instances show that piecemeal-incremental approaches reduce both average delays and their variability, thereby defying the power-law behavior. The paper offers three propositions for mitigating delays in the delivery of large-scale technological infrastructure: phased delivery, continuous learning from successful practices and experiences, and enabling learning capabilities.

Artificial intelligence in agile IT project management: A SWOT analysis

Carl Lorenz M. Canlas

Artificial intelligence (AI) is reshaping agile Information Technology project management by introducing automation and intelligent decision support. This study explores the strategic implications of AI adoption within agile frameworks through a SWOT analysis. A systematic literature review of 48 peer-reviewed studies was conducted to identify strengths, weaknesses, opportunities, and threats associated with AI integration in agile environments. The findings reveal that AI significantly enhances sprint planning, backlog prioritization, effort estimation, and software testing, resulting in faster development cycles, improved code quality, and better decision-making. However, these benefits require substantial workflow restructuring, investment in technology, and workforce upskilling. Weaknesses and threats are identified, but opportunities for scalable automation and hybrid human-AI collaboration look promising for organizations that adopt AI strategically. The study emphasized the importance of Project Management Technology Quotient (PMTQ) *as a critical competency for practitioners navigating AI-augmented workflows. By aligning AI capabilities with agile principles alongside robust governance models, organizations can optimize AI for sustained competitive advantage in the digital project economy.*

Understanding, experiencing, and applying Agile project management techniques: A scaffolded higher education assessment framework

Joy Garfield, Amrik Singh

By integrating industry needs with Agile project management education, higher education institutions and business organizations can help foster a workforce prepared for the dynamic, iterative, and collaborative modern business environment. Industries are seeking professionals who not only understand Agile project management techniques but can also respond to customer needs, collaborate effectively, communicate clearly, and adapt to change through experience and application. The assessment of Agile project management in higher education should therefore include these critical skills to meet current job-market requirements. This paper presents a case study of a UK-based university to demonstrate how students were exposed to industry expertise and experience, real-world challenges, and Agile project management tools and methodologies, encouraging active engagement and equipping them for the dynamic workplace. A scaffolded assessment approach was taken to encourage engagement, deep learning, and skills development.

We want to express our gratitude to all the authors who submitted their work for their insightful visions and valuable contributions.

We hope that you, the readers, find this special issue of the International Journal of Information Systems and Project Management an interesting and valuable resource for your continued work.

The Guest Editors,

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Middle Tennessee State University	*The University of Texas at Dallas*
USA	*USA*

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RESEARCH ARTICLE

Metrics champions: navigating challenges and driving change in software measurement program implementation

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Abstract
Research has been focused on technical approaches, leaving the behavioral and organizational aspects of metrics implementation underexplored. This study addresses this gap by adopting a job crafting perspective to examine challenges in metrics program implementation and how champions perceive and shape their roles to mitigate them. Based on a qualitative case study, we show that many difficulties arise from "soft factors," including unclear or conflicting objectives, misaligned expectations across teams, and weak communication channels. Without a shared understanding of metrics and their use, stakeholders interpret results inconsistently, undermining decision-making and engagement. Metrics champions actively craft their roles to address these barriers, taking on responsibilities such as educator, interpreter, and evaluator of data and tools. They also act as bridge builders and conflict mitigators, fostering collaboration and easing tensions among diverse stakeholder groups. These tasks, cognitive, and relational forms of crafting interact, enabling champions to move from passive adopters of metrics to active agents shaping the effectiveness of metrics initiatives. By combining job crafting theory and championing, we offer a human-centered view of software metrics implementation and emphasize the need for training and organizational support.

Keywords
software metrics; champions; job crafting; communication; blame game.

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1. Introduction

In today's data-driven and competitive environment, organizations increasingly rely on structured software measurement programs, defined as a socio-technical system composed of interconnected measurement systems (Staron & Meding, 2018). A measurement system, in turn, is "a tool used to collect, calculate, and report quantitative data to track and evaluate performance" (Staron et al., 2009). These systems operate as software-based mechanisms that gather data on various attributes (e.g., program size, product quality) and present it to stakeholders responsible for monitoring trends and making informed decisions. Building on this foundation, software metrics represent the core outputs of these measurement systems. A software metric can be understood as a function that takes software-related data as input and produces a quantitative value as output. This value reflects how a specific attribute influences the software product or process, thereby enabling consistent evaluation, comparison, and improvement efforts (IEEE, 1998).

Metrics are indispensable in the software development process for evaluating the progress of development teams (Kerzner, 2014), tracking performance and measuring success (Klein, 2022), and planning upcoming work (Székely & Knirsch, 2005). Metrics contribute to transparency and accountability by keeping track of issues that need to be resolved, encouraging productive and efficient behaviors for decreasing risks in software development (Spagnuelo et al., 2016). Despite the abundance of studies concentrating on the technical facets of metrics, such as their development (Kupiainen et al., 2015; Mitre-Hernández et al., 2014), reliability and use (Meding et al., 2021), the human aspects and social dynamics entailed in metrics implementation in organizations have not received the warranted attention (Berbyuk Lindström et al., 2025; Berbyuk Lindström et al., 2021; Matook & Maruping, 2014; Philipp et al., 2022).

Metrics as project management tools should be carefully selected to facilitate stakeholders' collaboration rather than hinder it (Rankinen & Haapasalo, 2025). Behind every number and dashboard, there's a human element that often gets overlooked. Metrics are more than just data points; they play a crucial role in helping people understand, trust, and use information effectively. To create real value with metrics, organizations must carefully consider *what* they measure, *why* they measure it, and *how* they do it and communicate those insights. When metrics are misinterpreted or poorly communicated, productivity and the overall work environment can suffer, leading to inefficiencies, resistance, stress and distrust (Suh et al., 2023).

Given the profound organizational changes that measurement programs often bring, successfully implementing them requires careful consideration of both technical and human dimensions (Goethert & Hayes, 2001; Hall & Fenton, 1994; Niessink & Van Vliet, 2001). In this context, individual actors often play a critical role in bridging strategic intentions and practical execution (Araújo et al., 2025). One such role is that of the champion. Champions are the individuals who take creative ideas (which they may or may not have generated) and bring them to life (Howell & Higgins, 1990). Champions make a decisive contribution to innovation by energetically promoting the idea, building support, overcoming resistance, and ensuring successful implementation. Typically, champions emerge spontaneously and informally within an organization (Schon, 1963), passionately identifying with the idea and its advancement to a degree that far exceeds formal job expectations. Over time, however, many organizations formalize the champion role through assigning explicit responsibilities, providing resources or authority, and integrating champions into structured innovation processes to harness their influence more systematically (Howell, 2005).

Extant research shows that involving change champions can be a highly effective strategy for rapidly implementing changes within an organization (Fernandez & Rainey, 2017; Miech et al., 2018; Renken & Heeks, 2019). Champions promote and facilitate the adoption of innovations or changes (Miech et al., 2018), helping their organizations in facilitating and moving through transformation (Drechsler et al., 2021). They typically possess strong interpersonal skills, leadership qualities (Nandan Prasad, 2024), and a deep understanding of the proposed changes, allowing them to effectively communicate the benefits, address concerns, and overcome resistance among their peers and stakeholders (Howell, 2005). Despite the plethora of studies concentrating on champions in different contexts, empirical research on champions is scarce in general (Shea, 2021), and in the context of measurement program implementation in particular (Korpivaara et al., 2021; Philipp et al., 2022). To address this gap, this study poses the following research question:

What are the challenges in metrics program implementation, and how do metrics champions perceive and shape their roles in mitigating them?

We address the question by analyzing data from interviews and workshops conducted over four years in a large energy sector company. Our study identifies key challenges in implementing software measurement programs, offering insights into the barriers organizations face when integrating measurement initiatives effectively. Further, using the theoretical lens of job crafting (Berg et al., 2013; Lazazzara et al., 2020; Wrzesniewski & Dutton, 2001), we explore how software champions perceive and shape their roles in mitigating these challenges. By connecting job crafting with championing, we contribute to the theoretical understanding of individual agency in measurement initiatives. This work lays the foundation for future research on the intersection of individual agency and organizational change in software development and beyond.

The remainder of the paper is structured as follows: We first provide an overview of relevant research and the theoretical framework guiding our study. We then present our research method and findings, followed by a discussion that informs both theoretical and practical contributions.

2. Previous research

This study is informed by several key literature streams: software measurement programs, job crafting, and champions in organizational change. Rather than viewing software metrics tools merely as instruments for data-driven management, they are understood as catalysts for organizational transformation. The success of this transformation depends on effective communication and employee engagement. In our research context, software champions play a critical role in this process, actively encouraging their peers to adopt metrics and adapt their work practices. Accordingly, our literature review explores software measurement programs, rooted in software engineering, job crafting, drawn from organizational behavior and management studies, and champions in organizational change, originating from information systems and communication research.

2.1. Software measurement program implementation

A software measure can be defined as “any tool that provides a quantitative assessment of the degree to which a software product or process possesses a given attribute, such as size, complexity, or quality” (Wallace & Sheetz, 2014, p.249). Organizations implement software measurement programs to oversee the software development process, uphold product quality, adhere to project timelines, and manage costs effectively (Nicolette, 2015). With this understanding, organizations can subsequently enhance both their processes and products.

There is a substantial body of research on software metrics (Fenton & Neil, 2000; Kupiainen et al., 2015), such as the development of software measurements, design of different types of software metrics, ensuring data quality and data accuracy (Fenton & Bieman, 2014) as well as various validation criteria (Meneely et al., 2013). Although some scholars argue that metrics enhance objectivity in management decision-making (Hall & Fenton, 1994), implementing metrics within organizations remains challenging (Berbyuk Lindström et al., 2021; Staron & Meding, 2018). These challenges stem from difficulties in defining clear objectives and purposes for metrics (Philipp et al., 2022), selecting appropriate metrics that align with organizational goals (Staron, 2012), and hurdles with choosing the right measurement tools (Boehm & Turner, 2005). Organizational resistance, resource constraints, and the need for skilled personnel further complicate the implementation of software measurement programs (Berbyuk Lindström et al., 2025; Sheffield & Lemétayer, 2013). Additionally, accurately interpreting data to generate actionable insights and ensuring the program’s long-term sustainability require ongoing effort. Managing ethical concerns and mitigating potential negative impacts on employee morale are also critical considerations (Cugueró-Escofet & Rosanas, 2017). These challenges extend beyond simply developing metrics for measuring code complexity, quality, and defect density; such complexities are fundamentally about people, their communication and collaboration (Lenberg et al., 2015), these soft aspects are especially relevant in teamwork, IT project management and adoption context (Assalaarachchi et al., 2025; Behn & Silvius, 2025; Ngereja et al., 2024).

In this study, we explore the implementation of software measurement programs within organizations, recognizing that such initiatives often encounter challenges related to “soft factors” like employee motivation and organizational culture. Resistance can arise when employees perceive metrics as unclear in purpose, disruptive to their roles, or misaligned with the company’s values, potentially leading to decreased morale (Cameron, 2011). To address these conflicts, it is crucial to understand the challenges and balance both “hard” and “soft” performance measures and incorporate employee feedback in the development of metrics (Berbyuk Lindstrom, 2023; Berbyuk Lindström et al., 2025; Kaplan & Norton, 2005).

2.2. Theoretical framework - Job crafting

Introducing software metrics into an organization and integrating them into management practices can lead to substantial organizational transformation. During these periods of change, change agents play a crucial role in promoting behaviors among employees that align with the organization’s goals and objectives (Petrou et al., 2018). However, during this process, change agents themselves also need to make sense of the changes and adapt their roles or job tasks accordingly.

Job crafting is defined as “the physical and cognitive changes individuals make in the task or relational boundaries of their work” (Wrzesniewski & Dutton, 2001, p. 179). The underlying assumption of job crafting is that employees are active agents who shape their work; through job crafting, they enhance the meaningfulness of their jobs and strengthen their work identities (Zhang & Parker, 2019). Wrzesniewski and Dutton (2001) identify three forms of job crafting: task, relational, and cognitive crafting. Task crafting occurs when employees modify their job by adjusting the number, scope, or type of tasks they perform, allowing them to reshape their responsibilities to better align with their skills or interests. Relational crafting involves altering the quantity or quality of workplace interactions, enabling employees to influence how often they engage with colleagues and the nature of those interactions, fostering stronger collaboration or reducing unnecessary exchanges. Finally, cognitive crafting refers to how employees redefine their perception of their work, whether seeing it as a series of disconnected tasks or as an integrated whole. Shifting this perspective can significantly impact how they approach their role and find meaning in their work.

Various factors can motivate job crafting, such as suboptimal job conditions or role ambiguity. Employees may engage in job crafting to gain greater control over their work tasks, enhance job autonomy, and improve job satisfaction (Grant & Parker, 2009; Griffin et al., 2007). Employees often undertake in job crafting during organizational change, as such transitions bring uncertainties. Rather than fixed duties, employees are typically given goals, which can create both challenges and opportunities. In navigating these changes, employees proactively shape their work environment to better align with the evolving demands, as well as their own values and interests (Walk & Handy, 2018). This proactive behavior helps them adapt to new job expectations (Berg et al., 2010; Wrzesniewski & Dutton, 2001).

2.3. Champions in organizational change

Extensive research in software engineering and information systems highlights the critical role of champions in driving innovation (Negoita et al., 2022), facilitating technology adoption (Chakrabarti, 1974; Heng et al., 1999), and ensuring project success (Beath, 1991; Cusumano & Selby, 1998). Beyond technical advancements, champions are instrumental in shaping organizational culture (Dong et al., 2007), influencing mindsets, and fostering change within their teams (Liker, 2004). Existing research also emphasizes the necessity of supporting these individuals through organizational resources (Reibenspiess et al., 2018), leadership development, and structural flexibility (Beath, 1991; De Clercq & Pereira, 2024) to maximize their impact.

Despite the recognized importance of champions in software engineering, empirical research on their role within software measurement initiatives remains limited. The field has historically focused more on technical and process-related aspects, with behavioral and human-centered dimensions receiving comparatively less attention (Lenberg et al., 2015). While research on software project leaders is well established (Shastri et al., 2021; Tabaka, 2006), examining the specific role of champions in software measurement is particularly valuable, as such initiatives often drive significant organizational change.

In our study, we adopt the perspective of job crafting in the context of organizational change, recognizing that champions do not merely participate in change: they actively promote and shape it (Bindl et al., 2019; Petrou et al., 2018). As proactive agents of transformation, champions must not only navigate evolving responsibilities but also redefine their tasks, interactions, and influence within the organization. Understanding how these individuals craft their roles can offer deeper insights into the behavioral dynamics of software measurement adoption and its broader implications for organizational success.

3. Participants and method

3.1. Setting and data collection

This exploratory case study was conducted between 2020 and 2024 through a combination of on-site visits and online sessions via Zoom and Microsoft Teams. The study focuses on a large international company in the energy sector, which develops both physical devices for sustainable energy generation and software systems for monitoring, regulation, and optimization. The company's software development teams are distributed across multiple countries in Europe and Asia.

We followed the implementation of the measurement program through continuous engagement with both management and developers. To support a smoother and more efficient implementation process, the organization in collaboration with the research team launched the "Metrics Champions Initiative." Drawing on prior research on championing (Negoita et al., 2022; Negoita et al., 2012) and in close collaboration with company representatives involved in the metrics program, we designed a step-by-step process for engaging metrics champions (Figure 1). The initiative began with the development of guidelines that defined the champions' roles, tasks, and responsibilities. These included supporting teams by providing guidance on metric interpretation, clarifying expected time commitments, facilitating communication among stakeholders to enable scalability, and embedding the use of metrics into daily organizational practices. The champion role was defined as part-time, accounting for approximately 20–30% of an individual's work time, allowing champions to integrate these responsibilities with their existing roles (e.g., product owner, business analyst, domain expert, or reporting specialist). Champions were recruited by managers leading the measurement program, who identified individuals demonstrating both interest in and expertise with metrics.

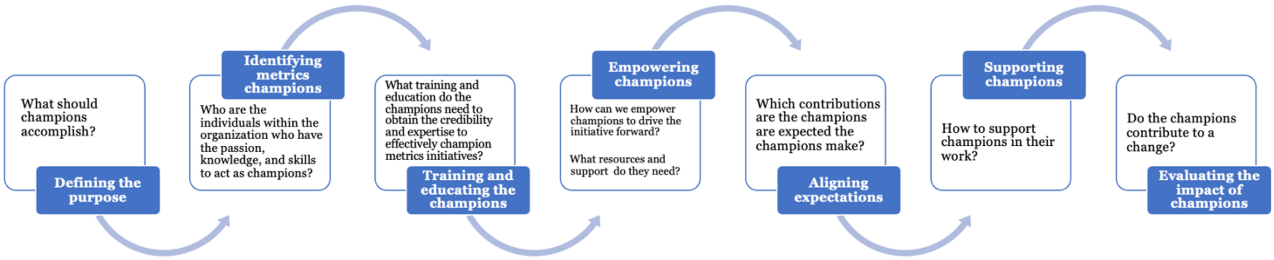

Fig. 1. Step-by-step process of metrics champions' involvement.

In total, 20 individuals were invited to participate in the championing process. The champions were not assigned ownership of specific metrics. Instead, they acted as part-time facilitators supporting multiple teams across the organization. Their role was intentionally cross-cutting: rather than maintaining or being accountable for particular metrics, champions assisted teams in interpreting measurement results, clarifying metric definitions, and providing feedback to improve data quality and tool development. Champions were selected from diverse departments and domains, ensuring broad organizational coverage without duplicating responsibility for the same metrics.

Champions primarily interacted with three groups: development teams, with whom they discussed measurement results and day-to-day challenges; managers, to whom they translated technical insights into decision-relevant information; and data and tool specialists, with whom they collaborated to address data quality issues and propose enhancements. This structure positioned champions as distributed connectors rather than metric owners, emphasizing communication, alignment, and organizational learning over formal authority or decision-making power. At the time of the initiative, both the organization and the champions focused primarily on software quality metrics, rather than on process performance or operational metrics.

The study draws on data from two 2.5-hour interactive workshops and 17 semi-structured interviews with managers and developers working with metrics (10 male, 7 female), as well as eight additional interviews with metrics champions (4 male, 4 female), including product owners, lead developers, release train engineers, quality managers, and domain experts. Participants were based in Germany, India, and Denmark and had between 1.5 and 22 years of professional experience. Each interview lasted approximately 45 minutes. The workshops and interviews with managers and developers focused on challenges encountered during the implementation of measurement programs. The interviews with metrics champions explored organizational understandings of metrics, implementation challenges, communication dynamics, and practices for mitigating these challenges. The champions were also encouraged to reflect on their experiences in their role. To ensure confidentiality, anonymity was emphasized, and participants were free to withdraw or reschedule their interviews at any time.

3.2. Data analysis

Descriptive field notes and anonymized transcripts from audio-recorded interviews and workshops were systematically collected and analyzed to ensure a robust examination of the empirical material. The research team collaboratively reviewed and discussed these materials to refine interpretations and enhance analytical rigor.

For data analysis, we employed a two-step, theory-informed approach using Atlas.ti software. In the first step, we engaged in open coding (Gioia et al., 2013), but not as a purely inductive exercise. Instead, our coding was guided by sensitizing concepts drawn from the literature, particularly research on metrics implementation, championing, and job crafting while still allowing the empirical material to shape how these concepts manifested in this context. This approach enabled us to identify salient themes and develop first-order codes that captured participants' experiences and practices. See Figure 2 for a data coding example.

In the second step, we iteratively linked the emergent themes to relevant theoretical frameworks, most prominently job crafting theory, to interpret the roles champions take and the challenges they address during metrics program implementation. This abductive movement between data and theory allowed us to refine our aggregated dimensions of task, relational, and cognitive crafting in ways that reflected both the empirical patterns and their theoretical underpinnings. Ongoing discussions among the researchers throughout the process ensured consistency in coding, interpretation, and theoretical integration, thereby strengthening the credibility and validity of our findings.

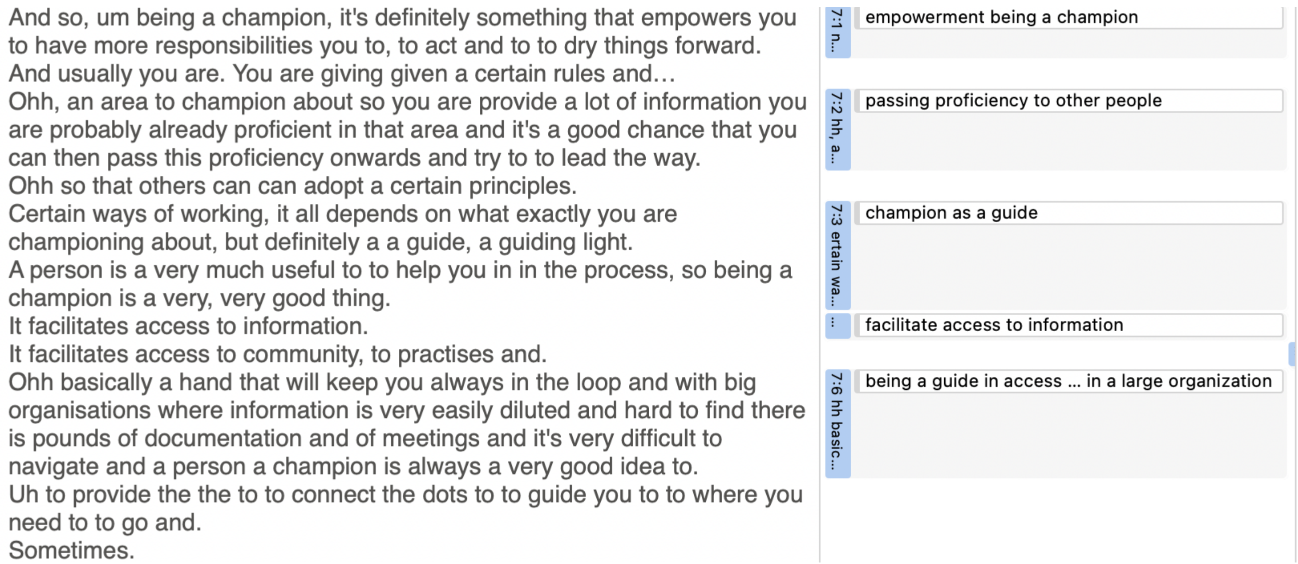

Fig. 2. Data coding example.

Because we had collaborated with the case company for four years, we entered the study with a strong understanding of its organizational context, its concerns about potential conflicts arising from software metrics, and its intent to position champions as facilitators of change. This background allowed us to focus the semi-structured interviews on the roles of champions without beginning from predefined hypotheses. Rather than starting with job crafting theory and testing it against the field, we let the data guide our theoretical engagement. As the interviews progressed, our iterative analysis revealed job crafting theory as a particularly fitting lens for understanding how champions shape their roles. The three forms of crafting, task, relational, and cognitive, proved especially useful for structuring and deepening our analysis of how champions navigate and mitigate challenges in the measurement program.

4. Results

First, we present a brief overview of the identified challenges, which the developers and managers experience in the process of measurement program implementation, followed by the analysis of how these challenges are mitigated by the champions taking specific roles.

Starting with the challenges, our analysis generated a total of 13 first-level concepts, which were further classified and aggregated into five second-level themes corresponding to the main challenges such as (i) an unclear purpose with undefined metrics; (ii) difficulties in interpreting measurement results; (iii) limited feedback about measurement and tool development; (iv) lack of alignment among teams and management across the organization; and (v) conflicts in metrics communication.

Turning to champions' roles in mitigating challenges, 14 first-level concepts were identified, then categorized and consolidated into five second-level themes, each representing a distinct role champions assume: (i) "metrics educators," focused on information sharing and educating others about metrics; (ii) "metrics interpreters," responsible for interpreting measurement results, facilitating feedback, and enhancing tool development; (iii) "metrics data and tool evaluators," dedicated to improving data and tool development; (iv) "bridge builders," bridging the gap between teams and management across organizations; and (v) "conflict mitigators," engaged in conflict prevention and resolution. Finally, we connected these five roles to core job crafting tasks, including task, cognitive, and relational crafting.

Figure 3 presents the analytical coding process used in the study.

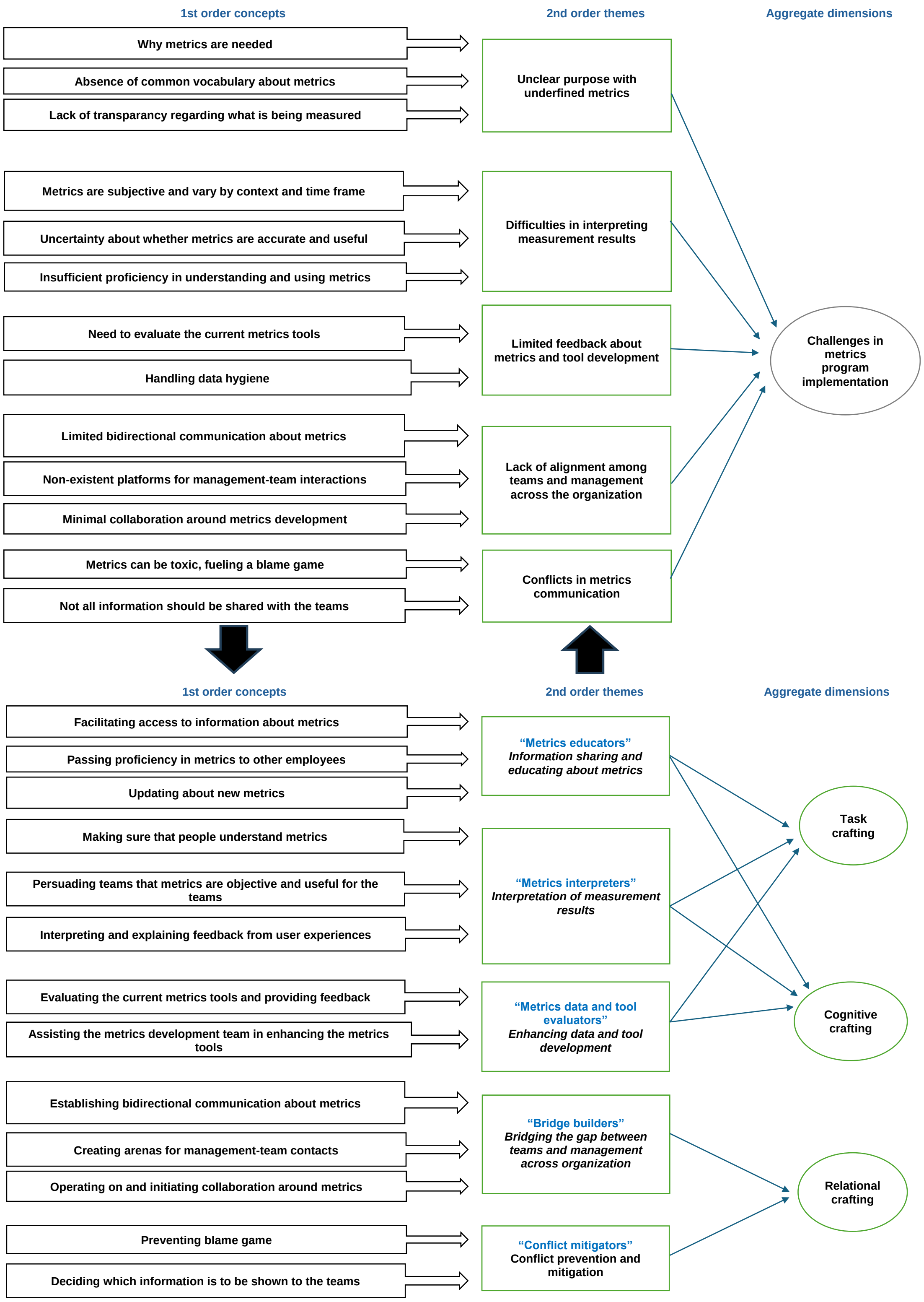

Fig. 3. Analytical coding process

4.1. Challenges in metrics program implementation

4.1.1. Unclear purpose with undefined metrics

Although developers and managers had a basic understanding of metrics, they emphasized the importance and urgent need to raise awareness about their purpose and the role they play in driving improvements and decisions:

"Why are we having the metrics? How do they help us in our overall value chain?" (Manager 1)

Further, there was a lack of shared terminology and a common vocabulary, which created confusion and inefficiencies across teams. Different teams were using different terms to refer to similar concepts, leading to misunderstandings and misalignment in how data and metrics were interpreted:

"Different teams seem to name stuff differently. In some cases, there is not even a name for stuff in which case we have to put a name on it, and we must put a name on it!" (Developer 3)

Transparency regarding what should be measured, how measurements are conducted, and why they are undertaken was identified as a critical issue in fostering a data-driven culture. Without transparency, teams struggled to understand the underlying motivations behind the metrics being tracked, leading to confusion, skepticism, and disengagement. When there is a lack of clarity about what is being measured, team members feel disconnected from the broader goals or uncertain about how their contributions fit into the larger organizational strategy. This transparency issue creates an environment where measurement feels arbitrary or disconnected from real value:

"We need to make sure that we are very careful on what we measure. Because if there's nothing wrong with measuring failed pipelines, but what does that tell you? So, we REALLY need to be very critical to ourselves on what is it not just take whatever cool things we can and just make it up." (Manager 5)

While respondents highlighted the importance of transparency, they also emphasized the need to carefully evaluate how much information to share, which information is most relevant, and how it should be presented to different stakeholders. Although managers rely on metrics to inform decision-making, they do not always have in-depth knowledge of metrics or the willingness to engage with the finer details. Therefore, ensuring that management gains meaningful insights without feeling overwhelmed by excessive information is crucial:

"Transparency should be good foundation, but it's also should be simple and not information overflow. And then maybe the trick is how developers can communicate it to management in a transparent way. That's exactly the challenge - how do you find a good balance?" (Developer 1)

4.1.2. Difficulties in interpreting measurement results

Interpreting metrics is not always straightforward, as it requires a deep understanding of both the data itself and the context in which it is being applied. Metrics may appear simple on the surface, but they often require nuanced analysis to uncover the insights they truly offer:

"We have our truth. And we have all our alternative truths, which are often represented through metrics. Information is well hidden in our dashboards." (Manager 4)

This statement highlights the challenge of navigating varying interpretations of data. Metrics can sometimes provide a fragmented or incomplete picture, making it crucial to be mindful while interpreting measurement results. Further, measuring alone is insufficient; one must not only capture the numbers but also interpret them within different contexts and at the appropriate time:

"The metrics will not have a value until associated with time. And importantly, the context of what, who and what they're looking at any given point in time. So that's the reason I try to see

subjectively and not objectively on the metrics because the actions that we want to take up on based on the metrics are time dependent. We also need to understand what those numbers mean. A number like 100% doesn't necessarily mean that everything is good. It never tries to say that whether it was done with quality, whether it was done on time, and for that I'll have to go back and try to look at how many open defects are there in that area of etcetera, etcetera." (Manager 4)

4.1.3. Limited feedback about metrics and tool development

Limited feedback about metrics tool development often leads to confusion and inefficiencies within an organization. While various tools were developed and implemented to track and analyze metrics, a significant issue arose from the lack of coherence and communication about which tools were being used and the rationale behind their selection:

"We need feedback. This is legitimate especially when we are working on developing new measurements. We need to constantly check: Does it work?" (Developer 9)

This statement highlights the importance of feedback loops to ensure the relevance and effectiveness of the tools being utilized. The absence of regular feedback also contributed to a fragmented ecosystem of software and systems across different teams. Many departments and teams developed own set of tools based on specific needs and priorities, which, while appropriate for their immediate tasks, led to a disjointed approach when looking at the organization as a whole. This fragmentation created significant challenges, as tools did not integrate well with one another, leading to inefficiencies in data sharing and communication between teams. Moreover, the lack of a unified strategy for tool development and implementation resulted in inconsistent data collection and analysis practices, undermining the quality of decision-making and the reliability of metrics across the organization. This issue was exacerbated by a lack of coordination between teams (see 4.1.4), which further complicated the alignment of tools with organizational objectives. Without a structured and ongoing process for gathering feedback, teams could not adjust or optimize tools as the organization's needs evolved, leading to outdated or underutilized systems. Furthermore, employees felt disconnected from the broader goals and vision of the company, as they could not fully understand the rationale behind the adoption of specific tools or how their work connects to organizational performance metrics.

4.1.4. Lack of alignment among teams and management across the organization

The respondents observed that the lack of alignment between teams and leadership was a significant barrier to achieving efficiency and fostering collaboration across departments:

"We can deliver something more innovative if we can get more information regarding how the metrics are used. We need to have additional discussions to go that extra mile to see what else we can get out of the data. We could cater for needs beyond what we can see, but it requires that we work more and better together!" (Developer 1)

This statement illustrates how the absence of a clear, shared understanding of how metrics are utilized limits innovation and prevents teams from fully leveraging data to meet organizational needs. When cross-departmental communication is lacking, as in our case, the potential for innovation diminishes, as teams are unable to explore alternative solutions or tap into a broader pool of insights that could help them achieve their goals. This misalignment was also evident in the strategic direction and day-to-day execution of tasks, particularly with respect to unrealistic expectations set by management:

"There is a need from 'above' [management] *to show a clear plan forward, and I think this is not the way to go, since there are so many uncertain dimensions to consider. It comes with unrealistic expectations. Why make grand roadmaps on [metrics] that are impossible to plan out all the way?" (Manager 2)*

This highlights the tension between top-down management directives and the reality of operational uncertainty. By imposing rigid roadmaps and expectations that do not account for the unpredictable nature of metrics development, leadership risks creating frustration and burnout within teams who feel constrained by unrealistic deadlines or objectives. Additionally, while individual teams focused on their specific goals and metrics, these objectives often failed to align with the broader organizational vision or the priorities set by leadership. This disconnects between departmental goals and overarching strategic objectives created inefficiencies, as teams operated in silos, working toward different outcomes without a shared understanding of how their efforts contributed to the company's larger mission. In such an environment, collaboration became challenging, and decisions could be made in isolation without considering the broader context or implications for other teams. As a result, the organization's ability to innovate, respond to feedback, or even simply execute tasks effectively became compromised.

4.1.5. Conflicts in metrics communication

While all participants agreed that metrics were indispensable for ensuring efficiency and product quality, there was a recognition of the need for balance in their application. One developer explained *"We don't want to ruin development time on something that isn't right"* (Developer 7), emphasizing the importance of using metrics effectively without disrupting the development process. At the same time, it was crucial to remember that metrics should not be used as a tool for blame:

> *"Efficiency measurement is not something you use to blame someone. It is something that we all need to have a close look at on a regular basis to fine-tune and adjust our plans and ways of working to get better." (Developer 5)*

This reflects a shared understanding that metrics should foster improvement rather than contribute to a toxic, punitive environment. Despite this consensus, several developers and managers pointed out challenges in the way metrics are communicated and perceived within the team. One developer noted that *"people are afraid to measure stuff. We don't show the good news as much as we show the bad news!"* (Developer 8), highlighting a tendency to focus on negative aspects, which creates a discouraging atmosphere. Another developer recounted their experience of quitting a task related to performance metrics, saying:

> *"Since I was forced to do this type of measures* [performance metrics]*, I just quit. Yes, start doing something else. Because I don't want to play a police officer. It's not OK!" (Developer 9)*

This sentiment points to the potential emotional and professional toll that a strict focus on metrics can have on individuals, especially when they feel compelled to enforce them in a punitive way. A manager, reflecting on this dynamic, emphasized the importance of trusting developers and avoiding micromanagement:

> *"Developers do not like to be pushed, micromanaged. We, management, need to trust them to do the right thing. They should not feel like management is hindering them to do a bad thing rather than allowing them to do the right thing!" (Manager 9)*

This trust was considered vital for fostering a positive work environment, where developers felt empowered rather than controlled by metrics. When providing negative feedback based on measurement results, it was noted that it is essential to avoid making the feedback "too personal." People become defensive when metrics are interpreted as personal criticisms, which can lead to unnecessary rivalry. This was particularly evident in situations where defect-related data or burndown charts were openly compared, potentially creating tensions within and among teams. Ignoring the context or failing to consider individual team dynamics could harm relationships, lower morale, and even result in talent loss.

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Metrics, if not handled carefully, could shift from being a supportive tool into a source of dysfunction, turning into a mechanism for blame rather than improvement:

> *"Metrics shouldn't be pressing; they should be 'un-pressing.' We shouldn't end up in people fading out and saying, okay, they are just judging me, right?" (Manager 1)*

4.2. Champions' roles in mitigating challenges

4.2.1. Task and cognitive crafting

Distinguishing between task and cognitive crafting roles in our data was challenging, as champions adjusted their perceptions of work while taking on new tasks to address challenges in the metrics program implementation. They reported adopting roles such as 'metrics educators' to focus on information sharing and education about metrics, 'metrics interpreters' to assist in the interpretation of measurement results, and 'metrics data and tool evaluators' to facilitate relevant processes.

Information sharing and educating about metrics

The champions played a crucial role in ensuring that the organization understood and effectively utilized metrics by taking a role of "metrics educators." They changed their perceptions from simply being involved in metrics development and passive delivery figures into the ones who were the ambassadors informing about metrics in the organization. Taking the task of "metrics educators" encompassed facilitating communication across various levels and departments, helping to "demystify" the purpose of metrics:

> *"I think one of the things that champions do is explain what metrics are used for, what is the purpose of the metrics to improve quality, information dissemination, and information collection." (Champion 1)*

This role was essential in creating a shared understanding of the metrics, ensuring that all team members were aligned in their approach to using data to improve operations and decision-making. The "educator" role was particularly critical in the early stages of the metrics program implementation, where knowledge about the tools and methodologies was still limited. During this phase, champions provided essential guidelines on how to work with the metrics, how to create new ones, and how to apply them effectively:

> *"In the beginning, we provided generic metrics guidelines on how to work with them, how to create new metrics and so on." (Champion 3)*

These efforts were vital for helping both managers and employees navigate the complexities of the new systems, ensuring that everyone could engage with and make use of the metrics to their full potential.

As educators, champions went beyond merely sharing knowledge. They actively contributed to raising proficiency across the organization. As one champion explained:

> *"As a champion, one is already proficient in that area, and it's a good chance that you can then pass this proficiency onwards and try to lead the way." (Champion 1)*

This leadership in knowledge transfer helped others improve their understanding and use of metrics. Beyond the technical instruction, champions were also able to inspire enthusiasm and foster a culture of continuous learning:

> *"I was enthusiastic to propagate this knowledge and to make sure that everybody gets the same level as I am." (Champion 4)*

This passion for sharing knowledge was not only about improving the team's technical abilities but also about instilling a sense of collective progress and ensuring that everyone had the tools and understanding necessary to succeed.

The champions' role was also integral in fostering an environment where information about metrics was accessible and everyone had the opportunity to develop their skills. By acting as educators, but even advocates for the metrics program, the champions helped with bridging the gaps in understanding and facilitated collaboration across departments. As the organization continued to grow and evolve, this culture of shared knowledge, enthusiasm for learning, and commitment to transparency created a solid foundation for the effective use of metrics in driving business success.

Interpretation of measurement results

Champions played a pivotal role in ensuring the accurate interpretation of measurement results, taking on the role as "metrics interpreters." This role was essential for fostering strategic alignment, enhancing accountability, promoting transparency, and ensuring that metrics were aligned with broader organizational goals. As one champion noted:

> *"I need to convince people in my surrounding that this were good metric, and we need to make sure that everyone understands the metric and that we do the same interpretation." (Champion 2)*

This responsibility underscored the champions' critical function in bridging the gap between raw data and actionable insights. Their work not only involved explaining metrics but also aligning diverse teams around a common understanding, ensuring that everyone interpreted the results consistently and correctly. Such transparency was essential to sustain confidence in the metrics and to ensure that decisions informed by data were both well-founded and strategic.

The champions recognized that the way metrics were interpreted and presented significantly influenced their impact on the organization: *"Who interprets matters the most and how it is presented by the interpreter also matters the most!"* (Champion 6). This highlighted the importance of the champions' role in not only providing data but also framing it in a way that was both accessible and meaningful to various stakeholders. Champions' task was to uncover valuable insights from metrics while enhancing overall understanding and trust within the organization. As another champion explained, part of their role was to *"work on the mindset of people,"* helping them to understand "*how to present things* [measurement results] *that they are really usable for the end users and easy to follow and understand!"* (Champion 1). This shift in mindset was key to transforming metrics from abstract data points into practical tools that could drive decision-making and foster a culture of continuous improvement.

Beyond improving understanding, champions played an essential role in guiding managers in the proper interpretation of measurement results, supporting fact-based decision-making. One champion remarked, *"We need to work very hard on creating definitions and good instructions to whoever uses these numbers at a high level"* (Champion 4). This focus on creating clear definitions and providing contextual instructions ensured that managers and decision-makers had the tools to use metrics effectively and make informed choices aligned with the organization's goals. The champions acted as navigators, helping management understand the full story behind the data and interpret it in ways that were relevant to the organization's evolving needs. Moreover, the need for interpretation extended beyond management to teams as well. A champion noted:

> *"Just showing numbers, e.g., checking a dashboard, is not enough! The managers check the dashboard to get a general picture, but for the team, I need to interpret what the data shows!" (Champion 5)*

This distinction emphasized the importance of champions in translating complex data into actionable insights that could be understood and acted upon at all levels of the organization. Without this critical interpretive role, taken by champions, teams might struggle to understand the significance of the metrics, leading to confusion and potentially misaligned actions.

To address the challenges of interpreting metrics, it was crucial for champions to possess not only a solid foundation of technical knowledge and experience with metrics but also access to a diverse array of real-world use cases. Knowledge and experience provided the technical understanding necessary to analyze and interpret data accurately, while use cases offered practical examples that contextualized the data, demonstrating how it was applied in real-world scenarios. These use cases highlighted best practices, common pitfalls, and strategies for success, helping to make more informed and relevant interpretations. By incorporating these examples, champions were able to bridge the gap between abstract concepts and the practical application of metrics across the organization, ensuring that their interpretations were both grounded in reality and aligned with the company's objectives.

Finally, managers recognized the importance of carefully assigning champions with the appropriate backgrounds to ensure they could effectively interpret metrics and facilitate understanding across the organization. One manager noted:

> *"If you have a champion who is very technical and maybe an architect or something of a solution, they can bring in completely different perspectives than having maybe a champion that is an RTE and is focusing on some other things." (Manager 4)*

This highlighted the need for diversity in the champions' backgrounds to ensure they could meet the various needs of different teams. Similarly, champions themselves acknowledged that translating metrics often required a solid understanding of the specific use case behind them:

> *"Some translation* [of metrics] *needs to happen, specifically when you talk to people who have a different background. If you want to translate that into a metrics requirement, you need to have a solid understanding of the actual use case behind it!" (Champion 5)*

Thus, having champions from diverse backgrounds was not just a preference but a necessity to ensure that the metrics could be interpreted correctly and applied effectively across the organization.

Facilitating feedback for enhancing data and tool development

The champions crafted an essential role as "metrics data and tool evaluators." Instead of being passive users and consumers of metrics, they took a proactive approach by examining the needs of various teams *"looking into our different scrum teams and trying to understand what [tools] are missing*" (Champion 4). One of the key insights shared by the champions was that incorporating data from multiple sources could provide a more comprehensive understanding of software quality *"a source of data is not enough. We need* [other] *sources of data as well to learn something about the quality of software!"* (Champion 2). By broadening the range of data sources, they aimed to ensure that the metrics offered a holistic view of the software's health, making them more reliable and effective.

Data hygiene was also a significant area of focus for the champions. One champion emphasized, *"If hygiene of data is not maintained, then whatever metrics is being projected might never be real"* (Champion 6). They understood that the accuracy and reliability of metrics were directly tied to the quality of the underlying data. The champions often worked closely with other teams to ensure that the data used for metrics remained clean and accurate:

> *"I don't prepare the data directly, but there are people in the organization who prepare and present the data. But the data comes from other people. The data is dependent on cleanliness and health. So, we work with* [name of a system]*, if information in* [name of the system] *is true, if we keep hygiene, then obviously that reflects into the metrics." (Champion 5)*

The champions also found themselves engaged in discussions about balancing the efficiency of using tools with the necessity of regularly updating data to maintain its accuracy. While management made efforts to streamline the process, the champions recognized the cultural challenges surrounding data hygiene practices. There was a growing concern about whether the tools were simplifying tasks or becoming burdensome. One issue raised was the frustration among developers who felt that the constant need to update data detracted from their core responsibilities. As one champion noted, part of their role was to contribute to finding the right balance between the ease of using tools and the requirement to maintain them. This tension required ongoing attention to ensure that the tools remained efficient and did not become an additional burden on the developers.

In addition to providing feedback on how metrics should be used, champions also stressed the importance of clarifying what metrics should *not* be used for. One champion highlighted the potential risks of using metrics in ways that could encourage undesirable behavior, such as tying them directly to KPIs that could lead to gaming the system:

> *"I think in the first place we do not use them* [metrics] *directly in the KPI's for people, that is super dangerous. So, people will not report the defects if they know that they can have some kind of bonus. You should be careful about that game!" (Champion 2)*

This caution reflected a deeper understanding of the potential for metrics to be misused if not carefully managed.

4.2.2. Relational crafting

Relational crafting role is related to crafting the boundaries of relationships in the work environment. The interviews revealed that two roles of "bridge builders" and "conflict mitigators" fall belong to relational crafting.

Bringing the gap between teams and teams and management across organization

In large organizations, such as the one studied, obtaining relevant information can be especially challenging due to the overwhelming volume of documentation and meetings. As a result, information can become lost, difficult to access, or diluted, making it hard to navigate and find the necessary data for informed decision-making. This is where the champions played a critical role as "bridge builders":

> *"Basically,* [a champion is] *a hand that will keep you always in the loop, and with big organizations where information [around metrics] is very easily diluted." (Champion 2)*

The champions served as key connectors, ensuring that relevant information did not get lost in the maze of internal communications and processes. By offering a clear point of contact, champions helped bridge the gaps in information flow, making it more manageable for individuals to access the data they needed.

To create a more collaborative environment, champions also initiated informal forums for the teams to meet to collectively discuss the metrics they were using. These forums provided a space for open dialogue about what statistics were most useful and where the teams were lacking in terms of data: *"We tried to see* [together with the teams] *what stats we are looking for and what can help us identify where we are lacking"* (Champion 6). By fostering these open discussions, the champions encouraged the free flow of information and feedback, which was crucial for identifying gaps, refining metrics, and ensuring that everyone understood the purpose and limitations of the data being used. These forums helped build trust in the metrics and created a culture of transparency, collaboration, and continuous improvement. As one champion expressed, this initiative helped to *"let the information flow"* (Champion 1), ensuring that the teams were always aligned and working toward the same goals.

Some champions also saw their role as a vital opportunity to facilitate connections across teams and management, regardless of their position in the organization: *"An opportunity to extend, to reach out, to connect people, to connect the areas, and get things moving"* (Champion 1). This bridging role was essential for ensuring that a shared understanding of metrics existed across the organization. By fostering alignment in how metrics were interpreted, champions helped drive informed decision-making, improve performance, and support the achievement of organizational goals. They believed that ensuring consistency in metrics interpretation was crucial for achieving broader objectives and maximizing organizational efficiency. As one champion noted, aligning metrics was not just about understanding them horizontally across departments, but also vertically, to ensure that the needs of different roles were met *"because you can have different needs for different profiles depending on what role the people have"* (Champion 7). With champions across various organizational levels, each offering unique value depending on their area of expertise, a shared language and understanding of metrics became possible.

To ensure that this shared understanding was achieved, champions emphasized the need for direct communication channels between those who needed the metrics and those who developed them. These champions saw themselves as the "*mold that makes things glue*" (Champion 1) and as an *"extended arm"* (Champion 8) of both teams and management, ensuring continuous, bi-directional communication and timely feedback. By actively fostering open lines of communication, champions helped keep the process fluid and responsive, addressing any concerns or discrepancies quickly. As a champion pointed out, a critical element of their role was *"demonstrating that we're listening"* (Champion 7). This collaborative spirit was essential for identifying common ground and facilitating smoother connections between various parts of the organization. Success hinged on eliminating barriers caused by siloed thinking and encouraging collaboration across teams:

> *"The key to success is bringing people together to collaborate and eliminating blockers caused by silo thinking, where each person focuses solely on their own tasks!" (Champion 5)*

This holistic approach also allowed champions to foster an environment where the flow of information was continuous, collaboration was prioritized, and organizational goals were clearly aligned and pursued efficiently across all levels.

Conflict prevention and mitigation

Another crucial social role of champions was mitigating the potential negative impacts of metrics, i.e. "conflict mitigators" recognizing that *"metrics can become toxic, so we want to avoid that"* (Champion 2). The delivery of critical feedback, particularly in a high-stakes environment, requires careful handling to avoid misunderstandings and conflict. Champions played an important role in preventing and mitigating conflicts related to the communication of measurement results. They did this by creating safe spaces for dialogue—arenas where team members could openly discuss concerns, ask questions, and address misunderstandings early on. By fostering a supportive environment, champions helped ensure that communication about metrics did not escalate into confrontations or resistance. As one champion explained, unsuccessful communication around negative results could lead to *"knee-jerk reactions which nobody wants"* (Champion 8), which further underscores the need for champions to manage the flow of feedback with care and diplomacy.

Conflicts often arise in the software development process when metrics, such as test results, reveal issues that affect multiple teams. A manager highlighted an example of how such conflicts could unfold:

> *"In software development, if you see tests as metrics,* [conflict situations happen] *because different teams have tests, and in many cases, different teams together build a software block. Each team has its own tests, and often one team's actions break something that another team is working on. Usually, the thing that detects this is the test. So, when a test fails, it can quickly turn into a blame game: 'Ah no, it was not US, it was THEM.' Then the other team says, 'No, it was not US, it was YOU. Ah no, it must be the TEST!' And sometimes, the people try to not only blame each other, but they even start blaming the METRICS." (Manager 7)*

This highlights the champions' role in establishing a *"culture of no blame, even though someone is making an error"* (Champion 8). The champions' approach focused on separating personal emotions from work-related issues, creating a space where feedback was about process and improvement, not individual performance. Another champion shared a method of handling conflict:

> *"I try to go to the facts and make it clear... I'm not questioning the work they've done because I think that what they've done is bad. I try to separate the personal from the work. The first thing is, 'Okay, this is not personal; I respect your work.' Then, I try to analyze if the metric is speaking the truth. If we both agree that it's accurate, the next step is to figure out what we need to do to move forward. I'm sorry, but if you accept the result, then it means that something you did caused the metric to show this number, and we need to address it. But the key is always to start by*

determining whether the test or metric is truthful and use that as the foundation for a constructive conversation where we remove the personal element and avoid blame." (Champion 3)

By creating a foundation of fact-based discussions and fostering an environment of trust, champions helped diffuse tension and focused the conversation on problem-solving rather than blame. Their role of conflict mitigators could guide teams through challenging feedback and encourage collaboration, being vital in maintaining a productive, non-toxic culture around metrics.

5. Discussion

This paper identifies the challenges in metrics program implementation and, by adopting the theoretical perspective of job crafting (Wrzesniewski & Dutton, 2001), explores the roles that "metrics champions" play in mitigating these challenges. While existing literature has extensively examined software metrics and championing in isolation, there remains a notable scarcity of empirical research that focuses on the intersection of these areas, particularly in relation to the role of champions in metrics implementation within organizations (Berbyuk Lindström et al., 2025; Meding et al., 2021). By discussing the "soft side" of software metrics, this study contributes to the growing body of research on the non-technical aspects of software project management (Mtsweni et al., 2016; Zaman et al., 2019). Implementing software metrics and integrating them into organizational management practices can trigger substantial changes within an organization (Moran & Brightman, 2000). A critical strategy in such transformations is the involvement of change agents, such as champions, who advocate for and facilitate the adoption of new practices that benefit the organization (Negoita et al., 2022; Petrou et al., 2018).

Starting with challenges in measurement program implementation, our findings indicate that they are often related to "soft factors" such as lack of shared understanding of the purpose of metrics, their objectives, and usage, lack of communication between teams and management, and presenting measurement results in a non-blaming manner. These factors have been overlooked in software metrics research (Hall & Fenton, 1994). Yet they are essential for driving organizational change and fostering a culture of accountability (Provera et al., 2010). One of the key challenges identified in the literature is the lack of clarity in defining the purpose and scope of metrics (Baroni, 2002; Berbyuk Lindström et al., 2021; Kerzner, 2023), without which stakeholders may be uncertain about what the metrics are meant to measure and how they align with the organization's broader goals, resulting in confusion, impeding effective decision-making and accurate progress assessment (Cokins, 2004). Our findings show that difficulties often arise in interpreting measurement results, especially when data is complex or not immediately actionable. Without clear guidelines on interpreting the results, stakeholders may struggle to make informed decisions, potentially leading to frustration and diminishing trust in the measurement system. Moreover, the absence of continuous feedback on the measurement process and the tools used for data collection can render these tools obsolete, reducing their relevance over time and contributing to disengagement among employees (Fenton & Bieman, 2014). This also echoes the recent research about the importance of feedback and mutual understanding between IT side and business side (de Araújo et al., 2025). Another challenge is the misalignment of goals and interpretations across different teams and levels of the organization. When different departments or teams operate in silos or have competing priorities, it can lead to confusion and inconsistencies in how metrics are applied and interpreted. This misalignment can hinder the effectiveness of the metrics, as it undermines the development of a unified approach to measurement. Furthermore, poor communication of the metrics and their results can exacerbate these issues, particularly when stakeholders interpret the data in conflicting ways (de Waal et al., 2019).

Turning to the metrics champions, we explore the connection between job crafting and champion theories, both of which emphasize self-initiated, transformative behaviors that shape work experiences and organizational outcomes. Our metrics champions tackled identified challenges by actively creating new roles and taking on initiatives to reinterpret and reframe the purpose of metrics, guiding their colleagues and ensuring alignment with organizational goals (Philipp et al., 2022).

Our findings highlight the roles champions developed during the measurement program implementation such as “metrics educator,” “metrics interpreter,” and “metrics data and tool evaluator,” all essential for addressing key challenges. Additionally, we observe the intertwined nature of task, cognitive and even relational crafting. While Wrzesniewski and Dutton (2001) distinguish between task, cognitive, and relational crafting, we note task crafting and cognitive crafting often co-occur in practice. Champions not only modified tasks but also shifted their perceptions of their roles at the meantime. They view themselves not as passive adopters of metrics, but proactive ambassadors of change. This cognitive view influences how they craft the tasks and relationships they engage in.

Furthermore, we identify two distinct relational crafting roles within the metrics context: “bridge builders” and “conflict mitigators.” The role of champions as conflict mitigators remains underexplored in the literature, yet our findings suggest it is crucial for preventing tensions (Husain, 2013) and fostering collaboration during metrics implementation (Hauschildt, 1999). Both roles emphasize the importance of communication and networking across teams, particularly in resolving conflicts arising from competing stakeholder interests or differing metric interpretations (Moran & Brightman, 2000). In our study, we also observe that relational crafting intersects with task and cognitive crafting, as building relationships and facilitating communication are central to both educating stakeholders and interpreting metrics effectively. Champions who educate and interpret metrics must also build relationships and mitigate conflicts, demonstrating that effective job crafting requires a holistic approach where different roles dynamically interact to drive meaningful organizational change (Husain, 2013). Here, we witness the intersection of job crafting and championing theories. While job crafting primarily focuses on an individual’s task and cognitive crafting, as well as forming relationships for personal benefit, championing is centered on building connections with others to achieve a specific goal, in this case, driving organizational change through the implementation of a measurement program. Given this distinction, it is unsurprising that relational crafting plays a more pronounced role in championing compared to other job crafting dimensions. Change is fundamentally about people, and metrics champions must influence them. Consequently, all champion roles inherently involve relational crafting elements, which are essential for effectively driving organizational transformation.

6. Conclusions

This study contributes to software measurement research by examining the multifaceted and evolving roles of metrics champions in navigating the human, organizational, and interpretive challenges of measurement program implementation. Our findings show that champions bridge technical and managerial perspectives, advocate best practices, and promote organizational learning by engaging in task, cognitive, and relational crafting. Rather than occupying fixed roles, champions continually negotiate and adapt their responsibilities—educating stakeholders, interpreting results, evaluating tools, building bridges across teams, and mitigating conflicts. Through these activities, they help shape shared meaning around metrics and ensure their constructive use in decision-making.

Our study contributes to the theoretical understanding of software metrics implementation by integrating job crafting theory with the concept of championing. Our findings highlight the interconnected, dynamic, and evolving nature of champion roles, offering a human-centered perspective on software metrics implementation that has often been dominated by technical considerations. Unlike prior quantitative research on job crafting, our study emphasizes the significance of individual agency and communication (Wawak, 2024) in driving the success of measurement programs.

For practitioners, our findings underscore the importance of empowering metrics champions to act as bridges between technical teams and management. Organizations should provide champions with clear mandates, time, training, and support to effectively promote best practices and foster a shared understanding of metrics. Furthermore, successful measurement programs require cultural alignment and establishing communication channels, not just technical implementation. Encouraging open dialogue and feedback can help prevent resistance and misinterpretation of metrics. Finally, improving data hygiene and reducing the burden of metric-related tasks on developers can enhance engagement, making measurement programs more effective and sustainable in the long term.

7. Limitations and future research

Despite these contributions, several limitations must be acknowledged. First, the study is based on a single case within a large energy-sector organization. While the context provides rich insights into distributed software development and measurement transformation, organizational culture and industry-specific practices may limit generalizability. Second, the findings rely primarily on qualitative interviews and workshops, which are susceptible to self-reporting biases and selective recall. Although perspectives were triangulated across developers, managers, and champions, subjective interpretation cannot be fully eliminated. Third, the study captures the implementation process at a specific moment in time. Metrics work and championing are dynamic and evolving, and a longitudinal design would offer deeper insight into how roles develop, stabilize, or change as measurement programs mature. Fourth, much of the analysis relies on champions' own perceptions of their role, while employees and managers may experience or interpret the champions' influence and activities quite differently. Fifth, the study does not systematically account for differences among types of metrics used within the case organization. Distinctions between process performance metrics (e.g., features delivered, cycle time), software quality metrics (e.g., maintainability, security, complexity), and operational metrics (e.g., response time, error rate) may shape how champions promote, communicate, and legitimize measurement practices. Because the analysis did not explicitly compare employee attitudes or championing behaviors across these categories, the findings may overlook important nuances in how different metrics are received, utilized, or supported. Finally, although job crafting theory framed the analysis, day-to-day work practices, interactions, and communication patterns were not observed directly.

Future research should employ longitudinal and more granular designs to explore how different job crafting roles emerge at various stages of a metrics initiative, how champions' influence evolves, and how organizational structures support or constrain their work. Combining qualitative methods with observational or quantitative data could further illuminate how metrics are interpreted, communicated, and enacted in practice, strengthening understanding of the human dynamics that underpin sustainable measurement programs.

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RESEARCH ARTICLE

Modularity, learning, and the mitigation of power-law distribution of delay in large-scale technological infrastructure delivery

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Abstract
Megaprojects, despite their crucial role in infrastructure delivery, consistently underperform in terms of time, especially when integrating technological innovations. Their reliance on the quantum leap approach struggles because of the temporary nature of project organizations and their inability to transfer experience across endeavors, producing a power-law distribution of delivery delays in which extreme overruns become inevitable. Grounded in the perspectives of system interdependency and self-organized criticality, our results from computer simulation of 50,000 instances show that piecemeal-incremental approaches reduce both average delays and their variability, thereby defying the power-law behavior. The paper offers three propositions for mitigating delays in the delivery of large-scale technological infrastructure: phased delivery, continuous learning from successful practices and experiences, and enabling learning capabilities.

Keywords
megaprojects; project design; learning; modularity; self-organized criticality.

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1. Introduction

Megaprojects are large-scale undertakings characterized by scale, extended delivery horizons, substantial financial investments, and far-reaching societal impacts (Flyvbjerg, 2014). They are often deployed to deliver complex systems intended to address major infrastructure development challenges. In 2017, global infrastructure investment was estimated to reach about $4 trillion for the years from 2016 to 2040 (Global Infrastructure Hub & Oxford Economics, 2017). Likewise, global spending on megaprojects was estimated to exceed $2.2 trillion in 2024 (Statista, 2024). These investment patterns span sectors such as transportation, energy, and urban development, contributing to economic growth and improvements in societal welfare through underlying technologies.

Despite these anticipated benefits, megaprojects frequently underperform as an infrastructure delivery approach, a phenomenon encapsulated in what Flyvbjerg (2014) terms the "iron law of megaprojects." A well-documented illustration of this is the United Kingdom (UK) NHS National Programme for Information Technology (IT). The system was expected to deliver benefits valued at £10.7 billion; however, it incurred costs of £9.8 billion, resulting in a £3.8 billion cost overrun and a six-year delay. The program was ultimately dismantled in 2011 (National Audit Office, 2013).

The underlying logic of megaprojects is rooted in the concept of a quantum leap (Ansar & Flyvbjerg, 2022), whereby changes in the system's structure must be both concerted and dramatic to minimize the duration of a turbulent, unsettling, and costly transition process (Miller & Friesen, 1982). However, the delivery of megaprojects is often protracted, exposing projects to multiple forms of turbulence that frequently result in poor performance (Denicol et al., 2020).

The delivery of technology-enabled infrastructure follows a different logic, as its objective is not only to construct innovative physical technological assets but also to develop technological innovations as an integral component of the infrastructure, with the intention of transforming infrastructure and, more broadly, society (Kipp et al., 2008; Tshabalala & Marnewick, 2025). This interplay between technological innovation and infrastructure delivery aligns with Hirschman's notion of the trait-making project, in which project owners are engaged in discovering the capabilities required to address specific technological problems (Hirschman, 1967).

In this regard, most trait-making projects lack a clear recipe for success and offer benefits that are uncertain or ambiguous. Consequently, project owners explore both the recipe for success and the benefits that these technologies may deliver during the course of infrastructure delivery (Liu et al., 2022; Nyman & Öörni, 2023). Moreover, trait-making projects create tensions for formal cost-benefit analysis, as many of the benefits associated with technological innovation for both project owners and society are difficult to quantify (McLeod, 2023). In this paper, we refer to the combination of technological innovations and infrastructure delivery as *large-scale technological infrastructure*.

Given the definition of trait-making projects as involving experimentation within a temporary organizational form, both successes and mistakes identified or explored in previous deliveries cannot be directly applied to subsequent projects, due to the absence of structural and organizational linkages between the past and present project organization (Denicol et al., 2021; Duffield & Whitty, 2015). In this vein, traits or capabilities are created and extinguished within individual projects due to the temporariness of the project organization, as well as the uniqueness of those traits which limits their direct transferability to other contexts (Flyvbjerg et al., 2024). As a result, lessons learned from other projects, both internal and external, tend to have limited relevance to the current delivery attempt.

In computer science research, the term "divide-and-conquer" refers to an approach that decomposes a complex problem into multiple modular, simpler subproblems, solves them, and then aggregates the solutions to obtain a solution to the original problem (Chen & Saad, 2009). By breaking down problems into small, modular components, humans can solve them more efficiently and with higher quality (Jacobs et al., 2007). This approach can serve as a building block for capability creation (Liao et al., 2010).

To retain and apply the traits developed through project execution, experience from previous projects should be treated as a continuum rather than as isolated episodes (Chhetri & Du, 2021; Volden & Klakegg, 2025). Accordingly, a modular delivery approach is required to retain experience throughout the infrastructure delivery process. Against this background, the research question of this paper is: *Can modular delivery approaches, combined with a learning mechanism, improve the on-time performance of large-scale technological infrastructure deliveries?*

To explore this research question, we developed a simulation model that proposes a framework for delivering large-scale technological infrastructure. The model employs the concepts of modularity (Baldwin & Clark, 2000) and learning (Argote & Miron-Spektor, 2011) to mitigate schedule delays in the delivery of large-scale technological infrastructure. We model the delivery of large-scale technological infrastructure through the lens of system interdependencies (Rinaldi et al., 2001), where delivery delays are represented by self-organized criticality (Bak et al., 1987), a key mechanism underlying IT project cost overruns (Flyvbjerg et al., 2022).

To build the framework, we run the model on synthetic data. The structure of a large-scale technological infrastructure delivery system in our simulation is based on prior research by Santolini et al. (2021). Our findings reveal that, by relying on a piecemeal-incremental approach, both the average level and uncertainty of schedule delays decrease with the number of delivery iterations. The reduction in delivery uncertainty is driven by learning effects and the modular delivery process.

We further substantiate this claim by fitting the simulation results to a power-law distribution, which characterises the behavior of IT project overruns (Flyvbjerg et al., 2022). Based on our findings, we present three propositions that offer novel insights into how project owners can effectively deliver large-scale technological infrastructure. These three propositions aim to advance our conventional wisdom on the delivery of large-scale technological infrastructure and may also be extrapolated to discussions on trait-making and capability-building projects.

This paper is structured as follows. In the next section, we relate our work to previous research on megaprojects as an infrastructure delivery process, project misperformance from a systems perspective, and studies examining how learning and modularity can lead to improved delivery outcomes. We then describe our simulation framework and the method developed to align the simulation outcomes to a power-law distribution. Our results are presented in a set of displays and are subsequently discussed. We conclude the paper with three propositions derived from the model's sensitivity analysis and discuss the paper's limitations and possible implications for future research and practice.

2. Related works

Megaprojects have long been conceptualized in the project management literature (Flyvbjerg, 2014; Merrow, 2011). Early work by Miller and Friesen (1982) introduced the "quantum view", which posits that organizations undertake major structural changes in a single, dramatic manner rather than through small, incremental adjustments. While incremental approaches can sometimes foster continuous improvement, Miller and Friesen (1982) argued that small changes in large systems either generate chaos or fail to produce meaningful improvements. Thus, the quantum view posits that if change is to be delivered, it should occur rapidly and dramatically, thereby minimizing the time spent navigating turbulence, disputes, and costly, unnecessary transitions. From this perspective, a megaproject can be understood as a process for achieving significant societal change. In this section, we review prior project management literature on the causes and prevailing responses to misperformance associated with using megaprojects as the preferred approach to delivering infrastructure, from a systems perspective. Further, we review the concepts of modularity and learning, which we propose as potential remedies. Finally, we integrate these concepts, arguing that both are required to address this persistent issue.

2.1. Megaproject as delivery process

Megaprojects aim not only to deliver infrastructure but also to develop and enhance technological knowledge. Hirschman (1967) referred to this type of project as “trait-making” projects, which seek to foster new skills, competencies, and capabilities. These outcomes typically extend beyond the immediate economic benefits of the infrastructure itself and contribute to broader societal change. If a trait-making project is successful, it generates values for society not only through its physical output but also through the social and behavioral changes it enables (Hirschman, 1967).

Despite this big ambition, most trait-making projects often end up as trait-taking projects, in which key capabilities and expertise are imported from other countries (Hirschman, 1967; Ika & Donnelly, 2017). Although outsourcing to specialized global firms can improve the odds of project management success (Davies & Brady, 2000), it can also be a double-edged sword for client organizations’ capabilities. A lack of owner-side competence, particularly in systems integration, can lead the owner to provide capital without control, thereby increasing the likelihood of project misperformance (Denicol et al., 2021; Winch & Leiringer, 2015). Thus, client organizations or project owners require foundational knowledge of both technology and project management, enabling them to function as system integrators who can orchestrate the interplay of multiple suppliers and align the project with their operational goals (Xia et al., 2024; Zani et al., 2024). However, the strong-owner model works well when the client organization seeks to expand its service portfolio, as it leverages system integration capabilities under the assumption that the project organization already possesses substantial technical and managerial knowledge—essentially implying that the means for achieving the desired outcomes have already been established (Denicol et al., 2021). Classic examples of strong project owners include the British Airport Authority (BAA) and UK Network Rail, which can be described as “megaproject-based firms” with existing service portfolios that benefit from the system or infrastructure being delivered (Denicol & Davies, 2022).

However, this approach may not be suitable when project owners lack the specialized knowledge required to govern complex projects due to the divergence from their core business (Winch & Leiringer, 2015). To compensate, public agencies often delegate system integration and management to external consultants or primary suppliers, prioritizing short-term delivery over the development of in-house capabilities and relying on the assumption of faithful delivery (Flyvbjerg & Sunstein, 2016). This reliance weakens oversight and diminishes the authority of project owners, creating a lock-in effect in which governments are forced to continue supporting delivery despite its challenges, as abandoning it could lead to political, financial, and social disputes (Altavilla et al., 2019; Hetemi et al., 2020).

2.2. Causes and cures of misperformance from a system perspective

Public infrastructures, particularly in sectors such as transportation, energy, and telecommunications, comprise extensive technological subsystems operating within a dynamic environment that encompasses a wide array of interconnected subsystems, activities, information flows, and resources (Abdoli & Kara, 2020; L. Chen & Whyte, 2022; Rinaldi et al., 2001; Vistnes et al., 2023).

The delivery of these systems involves reciprocal interdependencies, as subsystem adjustments create rework loops, thereby adding another layer of complexity to delivery (Bathallath et al., 2015; Söderlund, 2012). The existence of reciprocal interdependencies creates favorable conditions for self-organized criticality (SOC), in which a single disturbance can trigger a chain reaction that ultimately causes the entire system to transition into a critical state (Bak et al., 1987). For example, in IT projects, a failure in one activity can propagate structurally through reciprocal dependencies, driving cost and schedule overruns that follow power-law distributions (Flyvbjerg et al., 2022; Vazquez et al., 2023).

This critical state emerges from the system’s inherent complexity and interdependence (Santolini et al., 2021). However, given the limited empirical data in their study, it is inconclusive whether large-scale technological infrastructure delivery schedules or cost overruns follow the power-law distributions. System integration, defined as a governance process for managing complexity and uncertainty (Davies & Mackenzie, 2014; Whyte & Davies, 2021), mitigates the SOC phenomenon in infrastructure delivery by coordinating interdependent subsystems and actors, designing interfaces, and ensuring interoperability, stability, and managed change in subsystems across all phases of the project lifecycle (Zani et al., 2024).

In practice, system integration activities rely on dynamic control processes because initial information is often incomplete and must be continuously updated throughout the project lifecycle (Sanderson, 2012). Decisions made early, such as the project baseline during the design phase, must be revised later in response to changing conditions and stakeholder feedback (Chhetri & Du, 2021). To integrate systems effectively, especially in the delivery of technological infrastructure, a project organization possesses system integration capabilities to mitigate SOC by coordinating across different integration levels (Hobday, 2005; Lane & Boehm, 2008; Zani et al., 2024).

Despite the existence of system integration processes, the megaproject approach remains complex and uncertain, and there are no one-size-fits-all solutions for governing the complexity of infrastructure delivery (Geraldi et al., 2011; Nyarirangwe & Babatunde, 2019). System integration as a governance mechanism requires a certain level of knowledge from the project owner. Without sufficient system integration capabilities, the project is likely to misperform due to the inability to address the requirements of different phases and transitions and to unite all stakeholders (Denicol et al., 2020). For instance, the London Crossrail project faced significant delays due to underestimated system integration challenges during the planning phase (Whyte & Davies, 2021).

Similar issues occurred with the Berlin Brandenburg Airport project, where poor integration of technological subsystems contributed to extended delays and cost overruns (Luke et al., 2017). Outsourcing system integration capabilities can put project delivery at risk, as owners lose the ability to manage or even influence system-wide decisions; thus, it is important for project owners to build system integration capabilities to effectively manage the delivery, especially in public infrastructures where accountability and long-term operational concerns are paramount (Winch & Leiringer, 2015).

2.3. Organizational learning

Organizational learning positions knowledge as a key resource for firms to sustain competitive advantage. The organizational learning concept evolved from an interest in how organizations create, capture, and apply knowledge from the past to enhance current business performance (Argote & Miron-Spektor, 2011). This knowledge can be encoded and stored in various forms, ranging from tacit to explicit.

The organizational learning concept suggests that firms striving for long-term success should engage in building competence by upgrading skills and knowledge to align with the requirements set by their vision or mission (Yeo, 2003). In acquiring skills and knowledge, the organization must either extensively and iteratively explore choices, consequences, and outcomes or bypass this process by importing external knowledge (Longauer et al., 2024; Ngereja & Hussian, 2021). The outcome of learning is often most tangible in iterative processes, where agents are exposed to repeated identical tasks, leading to efficiency gains or cost reductions. This is the so-called learning curve effect, in which performance growth follows an inverse exponential function (Leibowitz et al., 2010; Wright, 1936). This function can be observed at all levels, from individuals (Kim et al., 2012) and teams (Muthulingam & Rajaram, 2022) to firms (Ryu & McCann, 2023).

In project organizations, the lessons-learned process is the primary mechanism for transferring knowledge by either codifying tacit knowledge into explicit knowledge through post-project reviews, documenting successes and failures to inform future teams (Duffield & Whitty, 2015; Project Management Institute, 2021; Volden & Klakegg, 2025), or by directly applying past tacit knowledge to current projects (Chhetri & Du, 2020). However, applying these insights in new contexts is challenging, as each megaproject is perceived as a unique, technologically sophisticated, and socially complex endeavor (Flyvbjerg et al., 2024), and because of knowledge loss during transitions between temporary and permanent organizational layers, as well as during conversions between tacit and explicit knowledge and vice versa (Denicol et al., 2021; Reich et al., 2014). By contrast, sectors where safety is paramount, such as aviation, rail, and healthcare, exhibit more structured approaches to institutionalizing lessons learned via compliance standards and iterative safety reviews (Duffield & Whitty, 2015).

2.4. Modularity

Modularity reduces system complexity by decomposing large systems into smaller, loosely coupled subsystems with standardized interfaces, enabling parallel development, component reuse, and scalable and flexible architectures (Baldwin & Clark, 2000; Xue et al., 2013). This approach enables the early detection of potential failures or design flaws before they propagate across the entire system (Xue et al., 2013). This modular system architecture is commonly adopted in industries such as automotive, software, and aerospace to enhance product variety without incurring major cost growth, thereby supporting economies of scale.

From a project management perspective, the benefits of modularity extend beyond the technical system being delivered. At the project organization level, modularity is crucial for determining how project team members should work together while minimizing complexity (Whyte & Davies, 2021). Standardizing methods and interfaces across teams not only reduces ambiguity in task execution but also streamlines communication protocols, thereby promoting consistent solutions among multiple suppliers on the project (Lammers et al., 2022). These practices are particularly important in megaprojects, where prolonged, multi-actor collaboration can lead to misaligned objectives or duplicated efforts (Hellström & Wikström, 2005; Phillips et al., 1999).

2.5. Summary of related works

The successful delivery of infrastructure through the megaproject approach relies on the project owner's ability to function as a competent system integrator. Project owner organizations that possess or actively build system integration capabilities can better orchestrate suppliers and align delivery results with their operational objectives. In contrast, those lacking knowledge of the technology and the delivery process often outsource system integration tasks to suppliers or consultants. In doing so, they transfer governance power to those firms. Such reliance can threaten project performance by weakening oversight and reducing the capacity to influence system-wide decisions, potentially leading to misalignment and underperformance in delivery. One way to mitigate these risks is to embed and maintain system integration capabilities within the project owner's organization. Organizational learning is crucial for developing and maintaining system integration capabilities in infrastructure delivery. However, this is often not the case when megaprojects are viewed as uniquely complex endeavors that restrain the application of lessons learned from within the organization or from others. The separation between temporary projects and permanent organizational layers further restricts the effectiveness of knowledge transfer. As a result, delays in megaprojects have become the norm, with on-time completion perceived as an outlier. This has led some recent project management scholars to call for alternative approaches to infrastructure delivery (Ansar & Flyvbjerg, 2022; Brunet, 2025; Thuesen et al., 2024). Figure 1 summarizes the flow of project owner system integration capabilities in delivering technological infrastructure under the megaproject approach.

In this regard, one promising approach to improving poor infrastructure delivery performance is to couple the modular delivery process with the learning mechanism. This allows project organizations to detect and resolve issues early, preventing them from cascading into system-wide crises by segmenting large-scale delivery into manageable, sequential modules. Each iteration becomes a live experiment, embedding technical and managerial insights directly into subsequent phases without relying on centralized knowledge storage in the permanent operational layer (i.e., infrastructure managers). This approach enables project owners to incrementally build system integration capabilities, mitigate SOC, and reduce the likelihood of project misperformance.

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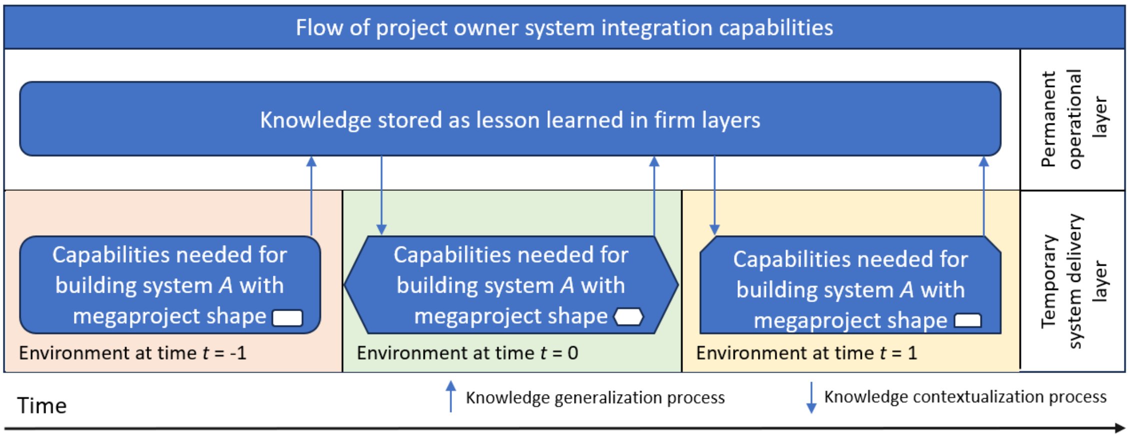

Fig. 1. Conceptual framework of project owner system integration capabilities flows under the megaproject approach.

3. Method

Theory building via computer simulation has a long tradition in management research. It offers a methodological sweet spot between theory creation and theory testing, leveraging the strengths of simulation methods, including high internal validity and the ability to handle longitudinal, nonlinear, and process-oriented phenomena that are difficult to reproduce experimentally or empirically in the real world (Davis et al., 2007). For modeling complex systems, stochastic simulation provides insight into how different sources of stochasticity influence system outcomes (Davis et al., 2007). To answer the research question, we developed a simulation model that draws upon project network structure, incorporating self-organized criticality as a source of project schedule overruns, as well as learning effects and modularity. We argue that these latter two constructs have the potential to reduce the magnitude of schedule overruns.

3.1. Simulation design

Based on the findings from Santolini et al. (2021), which reported a range of 282 to 50,101 activities in megaprojects, we specified 2,520 nodes to represent activities in a project activity network for delivering the entire infrastructure system. We chose that number based on our expertise in railway signalling projects, which typically involve 1500-3000 activities. To operationalize modularized infrastructure delivery, we divided the 2,520 nodes into delivery strategies, each comprising 1 to 10 module strategies. The number of activities assigned to each module in each strategy was determined by dividing 2,520 by the total number of modules.

The strategy comprising a single module is equivalent to the traditional megaproject approach, which involves 2,520 activities. For strategies containing two to ten modules, we assigned modules to be delivered sequentially, as this study aims to observe the effects of modularity and learning through self-experience (capability building) rather than knowledge transfer from parallel or past deliveries. Table 1 summarises the number of activities and modules associated with each delivery strategy.

Table 1. Number of activities (nodes) and modules of each delivery strategy.

Strategy	1 (megaproject)	2	3	4	5	6	7	8	9	10
Modules contained	1	2	3	4	5	6	7	8	9	10
Nodes contained	2,520	1,260	840	630	504	420	360	315	280	252

We then randomly generated a project activity network consisting of 2,520 nodes. The network's degree distribution follows a power-law distribution with a decay rate $\alpha = 2$ and a lower bound $x_{min} = 1$, based on prior research (Santolini et al., 2021). For each module, we assumed that completing each delivery task (node) takes one unit of time, and one node was randomly assigned to experience a delay.

For each module, we modeled the learning effect as the probability of successfully delivering a node using the standard exponential learning equation from Leibowitz et al. (2010), as shown in Equation (1), where n indicates the delivery iteration. P_n represents the probability that a randomly selected node will experience an overrun in delivery iteration n. E_{max} and E_0 represent the maximum and minimum task-delivery capabilities, with universal thresholds ranging from 1 to 0.01. a represents the project organization's learning capability coefficient, and A denotes the learning mode or strategy. A value of A of 0.5 implies that the organization learns equally from success and failure. A value of 0 means the organization learns exclusively from failures, whereas a value of 1 means it learns only from successes.

In our study, success is defined as on-time delivery, and failure as delayed delivery. If a previous attempt results in delay (failure) and $A = 0$, experience from that attempt increases the likelihood of success in subsequent attempts. Conversely, with $A = 1$, failed experience is not incorporated, and the probability of success remains unchanged. This logic also applies when the previous attempt is successful; under a failure-based learning strategy ($A = 0$), successful experience is discarded.

$$(1) \qquad P_n = E_{max} - (E_{max} + E_0) \cdot e^{-a \cdot A \cdot n}$$

Next, for each delivery module, if the effect of learning occurs, the selected node is not delayed, and its duration remains 1. This means that the duration of each delivery module will match the number of nodes contained in each strategy, and the total delivery time will be 2,520. When learning does not take effect, a delay phenomenon occurs, with the magnitude of delay ranging from 0.1 to 6, distributed uniformly. These magnitudes are based on our previous research on project schedule overruns for deliveries of European Railway Traffic Management Systems in the EU, where we treated these systems as large-scale technological infrastructure (Mahitthiburin et al., 2024).

The modeling of the delay phenomenon in this paper was conducted using self-organized criticality (SOC). We modeled this phenomenon in the same manner as Flyvbjerg et al. (2022) demonstrated for cost overruns. For updating module duration, we used the Breadth-First Search (BFS) algorithm to search all nodes connected to the randomly selected node within the project activity network, where all connected nodes would experience an identical magnitude of overrun as the source node as there is no guiding theory or empirical finding on the magnitude of the cascade effect, and based on optimism bias, the allocated buffer in each node is usually eliminated by top management; thus, we assigned no buffer to all nodes. To calculate the total duration of the entire infrastructure delivery, we aggregated the durations of all modules in each delivery strategy through summation. A summary of our simulation procedure is displayed in Table 2.

We ran the simulation 5,000 times for each delivery strategy, with the parameters in Equation (1) fixed at $a = 0.4$, $A = 0.5$, $E_{max} = 0.99$, and $E_0 = 0.01$. For each instance, both the module and total delivery times required to complete the project were computed, along with the magnitude and location of the delay at the source node under the scenario in which a delay occurs. Then, we computed the overrun ratio for all instances (module cost/node within the module), which were then used to fit the power-law and to perform descriptive statistics.

Table 2. Simulation step.

Procedure for the simulation
1. Create 2,520 nodes and randomly connect them, with the structure based on the results from Santolini et al. (2021).
2. For each module, assign a time to complete for all nodes in the network equal to 1
3. For each module, randomly select a node to experience
4. For each module, compute the probability of the selected node experiencing delay based on Equation (1)
4.1. Calculate the module duration if the selected node is not delayed.
4.2. Otherwise, the SOC phenomenon is simulated.
4.2.1. Randomly assign the overrun magnitude within a given range, as per Mathitthiburin et al. (2024), to the randomly selected node.
4.2.2. Search all nodes directly and indirectly connected to the overrun node using the Breadth-First Search (BFS) algorithm.
4.2.3. Update all nodes found in step 4.2.2. with the magnitude from step 4.2.1.
4.2.4. Calculate the duration of each module.
5. Calculate the total delivery duration by summing up the durations of all project modules.
6. Repeat steps 1-6, 5,000 times for each strategy

3.2. Fitting the delay phenomenon to power-law

This subsection describes how learning and modularity nullify the power-law nature of project schedule overrun. A power-law distribution is characterized as a statistical distribution in which the frequency of an event decreases rapidly as the magnitude of the event increases. In other words, it describes a phenomenon in which small or less impactful events are frequent, while significant events are rare but highly impactful. The key property of power-law distribution is that it has infinite variance. Earthquake size, for example, follows a power-law pattern, in which many earthquakes have small or unnoticeable impacts, while few have significantly large impacts (Clauset et al., 2009).

We used the synthetic data generated by our simulation in the previous section as input to determine whether it follows a power-law distribution, as described by the probability function in Equation 2. We repeated the power-law fitting method on the synthetic data under three strategies, 1, 2, and 5, to justify that learning and modularity can rule out the power-law behavior of schedule overrun. We employed the fitting procedure proposed by Clauset et al. (2009) to obtain the power-law fit of the schedule delay.

(2) $$f(x, x_{min}, \alpha) = \frac{\alpha-1}{x_{min}} \left(\frac{x}{x_{min}}\right)^{-\alpha}, x > x_{min}, \alpha > 1$$

4. Results

We presented our simulation results in two sections, in accordance with the method section: descriptive statistics and the power-law test. For each delivery strategy, 5,000 project activity networks were randomly generated in step 1, as illustrated in Figure 2. Our sensitivity analysis is presented and discussed along with the propositions in the discussion section.

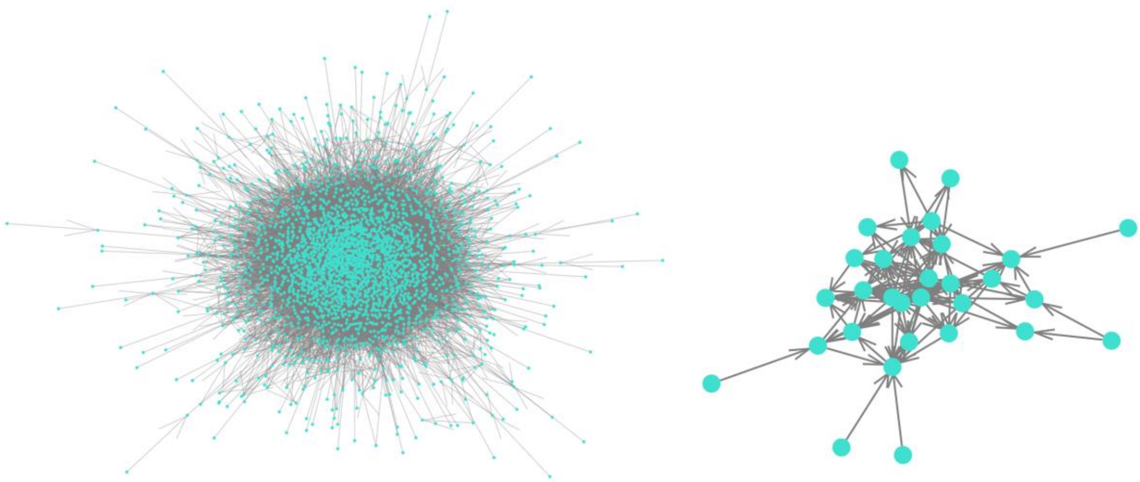

Fig. 2. Example illustrations of an activity network with 2,520 nodes (left) and 30 nodes (right), where the number of linkages follows a power-law distribution with decay rate α= 2 and x_{min} = 1.

4.1. Descriptive statistics

Table 3 presents descriptive statistics for the simulation results across 10 strategies, ranging from the traditional megaproject approach (strategy 1) to the iterative-modular approach (strategy 10). Each column captures the temporal dimension of infrastructure delivery performance. The average total delivery duration represents the mean time required to complete the whole infrastructure system across 5,000 simulation runs.

Although modularization does not dramatically reduce the mean delivery time, a clear downward trend is observable. The average duration decreases from 3,011.92 time units in strategy 1 to 2,893.35 time units in strategy 10, corresponding to an approximate 4.5% reduction. The average overrun ratio (defined as total delivery duration divided by the baseline duration of 2,520) follows a similar pattern.

The megaproject strategy gives an average overrun ratio of 1.1952, implying an average schedule overrun of nearly 20%. As modularity increases, the ratio steadily declines, reaching 1.1482 in strategy 10, equivalent to an average overrun of approximately 15%. Variance, however, benefits more. Strategy 1 gives a very high standard deviation of 855.69, indicating extreme variability and a high likelihood of unpredictable outcomes. In contrast, strategy 10 reduces this value to 283.89, representing a 67% reduction in variability relative to the megaproject approach. A similar pattern is observed in the standard deviation of the overrun ratio, which declines from 0.3396 in strategy 1 to 0.1127 in strategy 10. The maximum total duration column highlights each strategy's exposure to extreme delay events. The megaproject approach gives a maximum simulated duration of 11,637.66. As modularity increases, the upper bound of extreme outcomes decreases. For example, strategy 2 limits the maximum duration to 8331.06, while strategies 9 and 10 further constrain it to below 5,000 time units.

This reduction in worst-case outcomes underscores the resilience benefits of modular delivery, as cascading delays are increasingly contained within smaller subsystems rather than propagating across the entire project network. Macroscopically, both the average and the variance decrease in proportion to the number of modules. There is no significant reduction in the total average duration, which accounts for approximately 4.5% (comparing strategies 1 and 10); however, variance benefits more from our proposal, representing a 67% reduction (comparing strategies 1 and 10). This confirms that the iterative-modular approach provides a far narrower distribution of possible outcomes, making delivery performance more predictable.

Figure 3 complements these findings by visualizing the effects of the iterative-modular strategy. The boxplots of total delivery duration (Figure 3, right) show that while the medians and interquartile ranges remain relatively stable across all 10 strategies, the upper tails shrink substantially as the number of modules increases. Strategy 1 gives numerous extreme outliers, reflecting rare but catastrophic delays characteristic of power-law behavior. In contrast, higher-modularity strategies exhibit fewer and less severe outliers, indicating that extreme overruns become increasingly unlikely.

Figure 3 (left) illustrates the progression of the overrun ratio across delivery iterations. In the first iteration, when learning has not yet accumulated, more modular strategies experience higher overrun ratios because each module is delivered without prior experience. In contrast, megaprojects yield the lowest schedule overrun ratio. However, a clear tipping point occurs around iterations 3–4, after which modular strategies outperform the megaproject approach. Beyond this point, accumulated learning has a significant effect. This dynamic explains why modularity may appear disadvantageous in early phases but becomes superior as experience grows. Note that these results are valid when the parameters in the learning equation are set to $a = 0.4$, $E_0 = 0.01$, $E_{max} = 0.99$, and $A = 0.5$.

Table 3. Result of simulation with fixed parameters in learning equation: $a = 0.4$, $E_0 = 0.01$, $E_{max} = 0.99$, $A = 0.5$.

Strategy	Average total delivery duration	Average overrun ratio	S.D. of total duration	S.D. of ratio	Maximum total duration
1	3011.92	1.1952	855.69	0.3396	11637.66
2	3012.24	1.1953	637.41	0.2529	8331.06
3	3025.63	1.2007	545.68	0.2165	7335.99
4	3005.64	1.1927	462.68	0.1836	6441.74
5	2988.97	1.1861	420.86	0.1670	5645.09
6	2968.20	1.1779	387.05	0.1536	5524.88
7	2947.68	1.1697	346.08	0.1373	6025.54
8	2925.31	1.1608	321.20	0.1275	5313.16
9	2913.37	1.1561	297.24	0.1180	4830.58
10	2893.35	1.1482	283.89	0.1127	4861.60

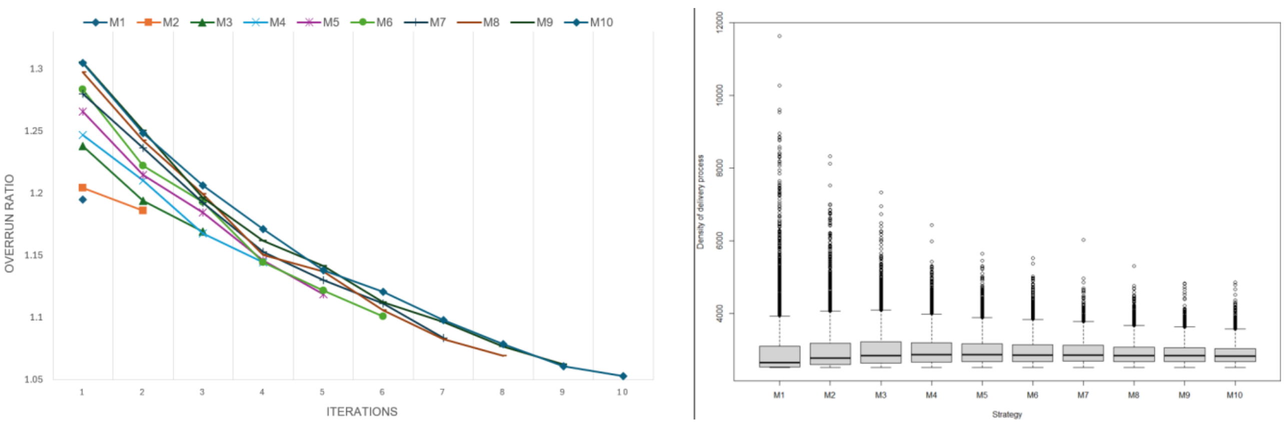

Fig. 3. (Left) Overrun ratio per iteration among 10 strategies. (Right) Boxplot of each strategy.

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4.2. Ruling out power-law behavior

The analysis investigates the statistical behavior of schedule delay through power-law fit across three delivery strategies (1, 2, and 5) to understand how the increase in module and accumulated knowledge nullifies the fat-tail behavior of total project overrun. Table 4 summarizes the results of fitting our simulation results from the three selected strategies to power-law, based on the procedure outlined by Clauset et al. (2009).

The table shows that the megaproject approach (strategy 1) can be explained by a power-law distribution with a decay rate (α) of 5.01 (p-value = 0.1). This fat-tail behavior of the megaproject approach highlights its susceptibility to rare, large delays. However, the other two strategies do not fit the power-law pattern (p-values $\leq$ 0.01 for strategies 2 and 5), meaning that the likelihood of extreme overrun is lower than in the megaproject approach.

Figure 4 shows visual evidence of the power-law fits for three strategies: the left panel shows strategy 1 (megaproject), the middle panel shows strategy 2, and the right panel shows strategy 5. The figure illustrates the cumulative density functions (CDFs) on a logarithmic scale (y-axis). The red lines represent the maximum-likelihood power-law fit. The CDF of strategy 1 closely aligns with its red power-law fit (α = 5.01, p-value = 0.1), confirming power-law behavior.

However, the CDFs of strategies 2 and 5 deviate significantly from the power-law fit (p-values $\leq$0.01) due to the early drop in their high regions (overrun ratios of approximately 2 and 1.6 for strategies 2 and 5, respectively), leading to a divergence between the theoretical power-law fits and the empirical CDFs. The implication is that strategy one can be explained by a power-law distribution, which highlights its vulnerability to severe delays, while strategies 2 and 5 demonstrate how modularity and learning nullify the fat-tail behavior.

Table 4. Basic parameters of each strategy, along with their power-law fits and the corresponding p-value.

Strategy	Mean	S.D.	x_{max}	Power-law x_{min}	α	n_{tail}	p-value
1	1.20	0.34	4.62	1.11	5.01	1902	**0.10**
2	1.20	0.25	3.31	1.04	6.40	3450	0.01
5	1.18	0.17	2.24	1.17	9.13	2077	0.00

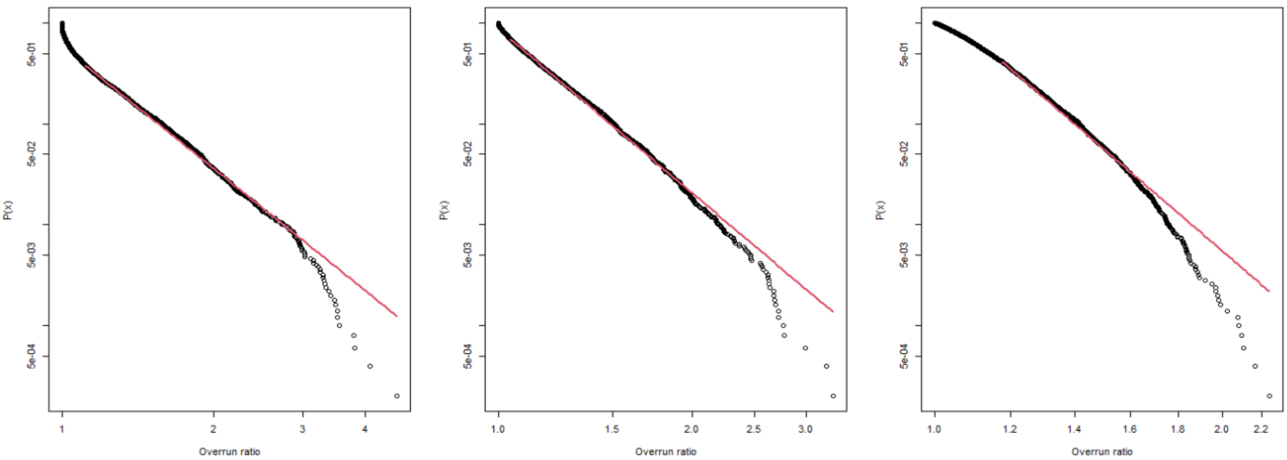

Fig. 4. Cumulative density functions (CDFs) on a log scale of the project schedule for the three strategies.

We also used Vuong's test to determine the best-fit distribution for each strategy. The contested distributions are log-normal, exponential, pure power-law, and power-law with exponential cut-off. We used a pure power-law distribution as the baseline for comparison. Table 5 reports the *p*-value for each strategy's fit to the power-law model, with statistically significant values highlighted in bold. Additionally, the table includes likelihood ratios (LR) and *p*-values from Vuong's test. Negative log-likelihood ratios indicate that the alternative model offers a better fit than the pure power-law model. The corresponding Vuong's test values are shown to the right of the LR column, with significant values in bold. The rightmost column indicates our verdict.

For strategy 1, the power-law with an exponential cut-off distribution provides a better fit to our phenomenon than the pure power-law (LR = -2.54, *p*-value = 0.02). In comparison, the other two distributions offer a non-significantly better fit compared to the power-law. Vuong's test of strategy 2 favors alternative models over pure power-law: power-law with cut-off (LR = -7.2, *p*-value = 0.00) and log-normal (LR = -6.20, *p*-value = 0.03. Strategy 5 rejects the pure power-law distribution, as Vuong's test favors all alternative distributions over it, as explained by the LR values (log-normal = -38.85, exponential = -36.14, power-law with cut-off = -37.6). Overall, modularity and learning nullify power-law behavior, as strategies 2 and 5 do not fit with pure power-law and can be explained by simpler distributions with finite variance, implying that the likelihood of being highly delayed is truncated.

Table 5. Test of best-fitted distribution.

Strategy	Log-normal		Exponential		PL + cut-off		Supporting distribution
	LR	p	LR	p	LR	p	
1	-1.43	0.28	34.66	0.00	**-2.54**	**0.02**	power-law, power-law with cut-off
2	**-6.20**	**0.03**	5.73	0.46	**-7.2**	**0.00**	power-law with cut-off, log-normal
5	**-38.85**	**0.00**	**-36.14**	**0.00**	**-37.6**	**0.00**	power-law with cut-off, log-normal, and exponential

5. Discussion

Delivering large-scale technological infrastructure through the megaproject approach presents significant challenges due to the inherent complexity and uncertainty. Prior research suggests that the magnitude of overruns follows a power-law distribution due to the growth of project activity networks and their increasing interdependency (Santolini et al., 2021; Vazquez et al., 2023).

While traditional megaprojects (strategy 1 in the simulation) exhibit the lowest average schedule overrun ratios in the initial iterations (Figure 3), their rigidity makes them more vulnerable to uncertainty than the iterative-modular delivery approach. Moreover, our findings reveal that the delay of the megaprojects approach follows a power-law distribution with a decay rate $\alpha = 5.01$ (Table 4), indicating that the schedule ratio has a finite mean and variance but retains a heavy tail of extreme delays ($x_{max} = 4.62$, Table 4). This fits well with the power-law with exponential cut-off distribution (Table 5), in which catastrophic delays are still possible but rare.

In contrast, iterative-modular delivery strategies (e.g., strategies 2 and 5) nullify the power-law behavior of delivery delay as these two strategies yield significantly higher power-law decay rates ($\alpha = 6.40$ and $\alpha = 9.13$, respectively, Table 4), ruling out power-law behavior (Figure 4), and shifting the delay pattern to distributions with finite variance (e.g., log-normal, Table 5), minimizing the likelihood and magnitude of extreme delays.

The megaproject approach may appear advantageous initially (Figure 3). However, the likelihood of achieving such a performance is relatively low due to the high variability of the outcome. Macroscopically, modularity and learning slightly lower the average delays but drastically reduce the variability (Table 3). For instance, strategy 10 achieves a 4.5% reduction in total duration and a 67% decrease in variance compared to the megaproject approach. However, our results provide a lower bound on the overruns of all strategies due to model simplification, which assumes a single unit-time cost for all activities and a single SOC's source-node assignment per iteration.

Based on our analysis, we will, in the following paragraphs, propose three propositions to enhance the efficacy of delivery through modular iteration, which are:

- *Proposition A: Design a delivery approach that includes phased implementation.*
- *Proposition B: Continuously learn from previous successful practices and experiences.*
- *Proposition C: Design the delivery process to enable the effect of learning capability.*

5.1. Proposition A: Design a delivery approach that includes phased implementation.

Our results suggest that the project owner's initial capability matters for delivery performance. Its effect on the average duration over iteration is somewhat linear. However, it results in an exponential decrease in variability (Figure 5). With initial capability at its maximum ($E_0 = 1$), both the average and standard deviation of the total project duration are minimal, and all strategies experience approximately a 1% overrun (Figures 5 and 6). This means that trait-taking projects, where experts have a clear understanding of what to do, are less likely to be delayed.

For the trait-making projects, the average results would yield similar outcomes once the system was built in the 10th iteration, assuming a constant learning capability; however, variability is slightly higher (Figure 6). When a project owner delivers large-scale technological infrastructure with a low initial capability ($E_0 \approx 0$), the megaproject approach results in the highest average delay and variability, as indicated in the lower-left cell of Figure 5. In contrast, the iterative-modular approach yields lower average delay and standard deviation for the entire endeavor.

In situations where there are no initial capabilities for governing and executing the endeavor, the delivery process becomes as critical as the system itself (Ika & Donnelly, 2017); therefore, project owners delivering large-scale technological infrastructure without prior experience in governance and execution should adopt an iterative, modular delivery approach. Unlike the megaproject approach, which relies on exhaustive upfront planning, iterative-modular approaches allow incremental adjustments based on real-world feedback, which aligns with the nature of system integration in practice (Sanderson, 2012).

In an iterative-modular approach, the first iteration serves as both a prototype of the system's infrastructure and a testbench for improving the delivery process. The first iteration helps mitigate uncertainty by translating it into risks, enabling the identification and resolution of errors before full-scale deployment. This first iteration allows stakeholders to learn about the technological infrastructure itself and the delivery process in a real-world environment on a smaller scale, building the capabilities for delivering the technology, the essence of trait-making projects from Hirschman, which he defined the definition of success of trait-making projects as "for the project if it is successful, will be valuable not only because of its physical output but even more because of the social and human changes it will have wrought" (Hirschman, 1967, p.119).

The first iteration establishes credibility and public trust in both the delivery process and the system being delivered (if it is successful), as infrastructure delivery often faces systemic inefficiencies and governance failures, leading to delays and unmet expectations that provoke stakeholder skepticism (Altavilla et al., 2019; Hetemi et al., 2020). A successful first iteration provides empirical evidence of feasibility, effectiveness, and societal impact within its context, creating buy-in for the broader implementation. If it fails, the endeavor can be discontinued with minimal investment loss in the first phase.

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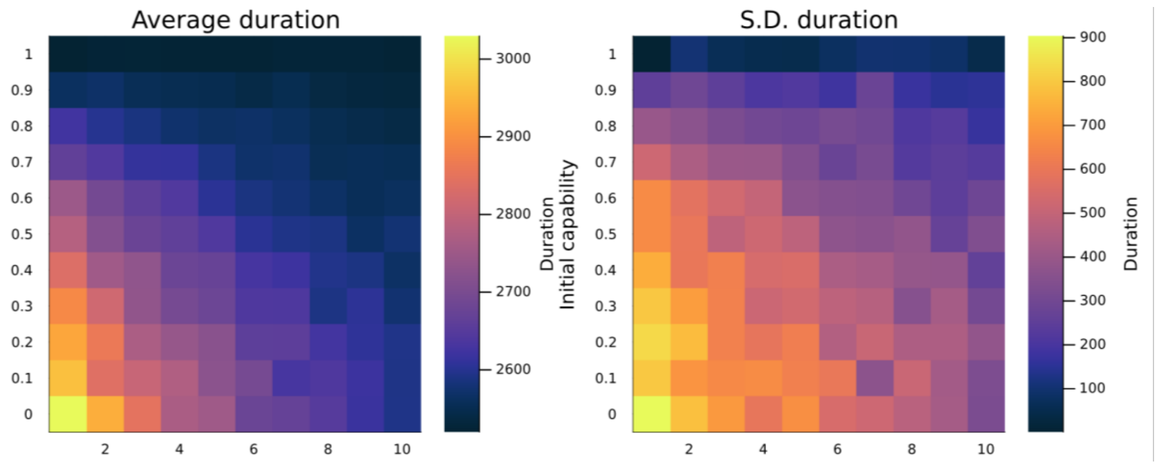

Fig. 5. Initial capability (E_0) (Y-axis) with delivery iterations (X-axis) on average and standard deviation of total overrun with fixed parameters, A = 0.5, Number of activities and baseline duration = 2,520, a = 0.4, E_{max} = 0.99.

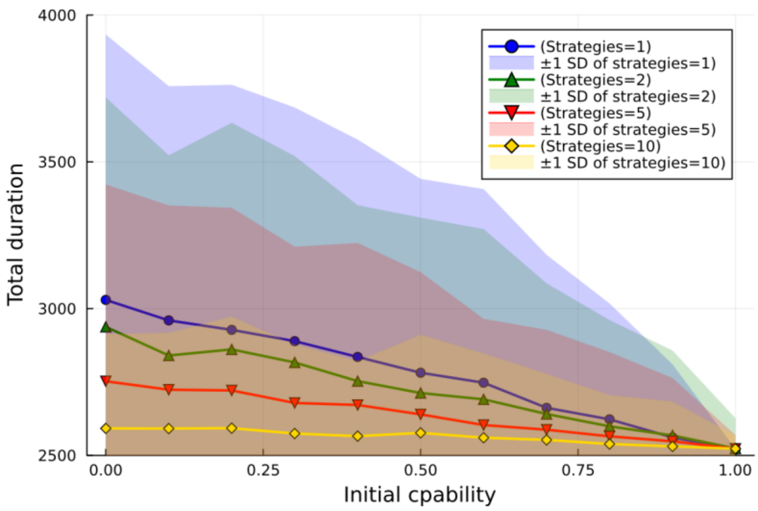

Fig. 6. Initial capability (E_0) under four strategies (1, 2, 5, and 10) in terms of the average and standard deviation (S.D.) of total duration, with fixed parameters: A = 0.5, number of activities and baseline duration = 2,520, and a = 0.4.

5.2. Proposition B: Continuously learn from previous successful practices and experiences.

Overall, our findings support the notion that learning by doing reduces production costs and uncertainty (Ryu & McCann, 2023); however, there are two ends in the learning mode spectrum: success and failure. From our simulation, we observe that the success-based learning mode has a more substantial effect on both average duration and variability than the failure-based learning mode (Figure 7), supporting the findings of Baum and Dahlin (2007) and Muthulingam and Rajaram (2022) in other contexts.

We notice that the delivery of technological infrastructure and movie production operations shares similarities. In both contexts, each team member performs distinct tasks in coordination with others. When teams are composed of members with a history of success, each member will perform their task using the experience that led to past success, which can mitigate the impact of time pressure and contribute to the success of the current production (Muthulingam & Rajaram, 2022). In this vein, relying on histories of small successes with the iterative-modular approach rather than placing a big bet on the megaproject approach yields better overall performance on the delivery schedule (Figure 7).

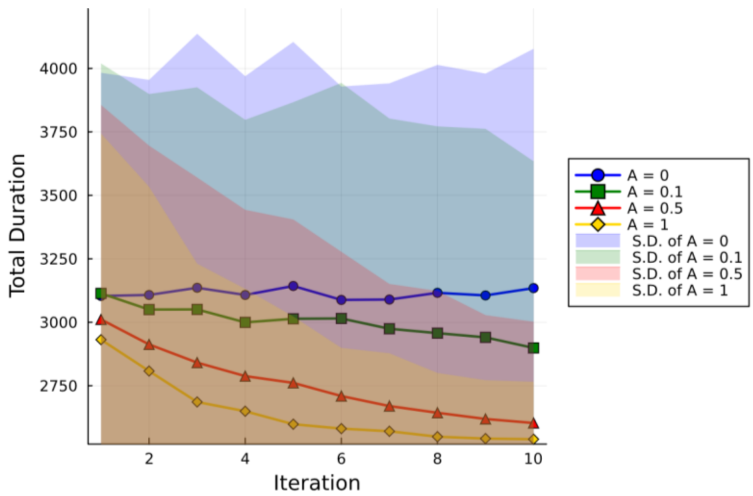

Fig. 7. The effect of learning mode on the reduction over iterations. *A* = 0 (failure-based learning), *A* = 0.5 (learning equally from success and failure), *A* = 1 (success-based learning). Number of activities = 2,520, *a* = 0.4.

Technological infrastructure prospers when it is institutionalized in society. The imported delivery process, although proven effective in its original contexts, may not be directly applicable to the country's unique conditions. Trait-making projects are not only about delivery infrastructure but also about building knowledge regarding their delivery. Knowledge of how to make (deliver) things is considered art, not science (Aristotle, 350 BCE/2009); thus, to excel in art, one must go through iterations of practice. Once these practices prove successful, they become embedded within routine as tacit knowledge, which can enhance the likelihood of successful innovation and decision-making (Longauer et al., 2024; Ngereja & Hussian, 2021).

Technologies are often developed through trial and error due to the inherent complexity and uncertainty of the process (Sommer & Loch, 2004). From the outset, knowledge about delivering large-scale technological infrastructure cannot be science but art, according to Aristotle's definition of knowledge, which requires understanding logic and experience for the development of knowledge (Aristotle, 350 BCE/2009).

In our context, scaling and sustaining technological infrastructure requires a project owner to continuously learn from past successful practices and experiences, generating experiential knowledge. By embedding identical experiences from the previous infrastructure delivery directly, the project owner can benefit from the continuous harvesting process of knowledge that can be directly exploited without generalization and contextualization processes, as displayed in Figure 1, to develop best practices tailored to specific conditions through adaptation and alignment processes, the two of the essences of trait-making projects (Ika & Donnelly, 2017).

5.3. Proposition C: Design the delivery process to enable the effect of learning capability.

Infrastructure delivery is time-consuming and highly vulnerable to volatility in the project environment, making adaptability and flexibility essential (Davies & Brady, 2000; Denicol & Davies, 2022). This adaptability is particularly crucial in large-scale infrastructure delivery, where project environments continually evolve (Geraldi et al., 2011; Nyarirangwe & Babatunde, 2019). Based on a sensitivity analysis of learning capability, we found that both the mean and the variability of delivery duration decrease exponentially as learning capability increased across iterations (Figure 8). This sensitivity analysis indicates that institutionalizing iterative learning in the delivery process can improve efficiency in large-scale technological infrastructure projects.

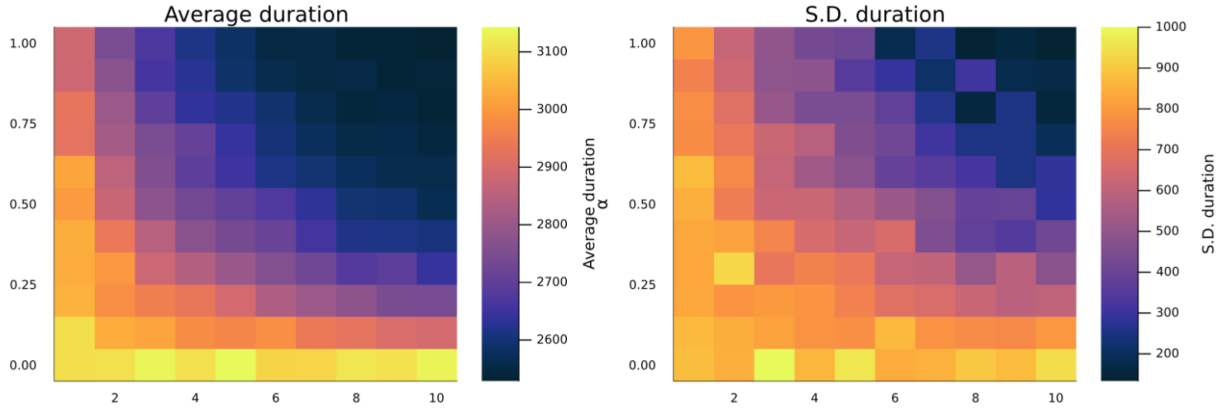

Fig. 8. The effect of learning capability (α) (Y-axis) with delivery iterations (X-axis) on average and standard deviation of total overrun in absolute value with fixed parameters, A = 0.5, number of activities, and baseline duration = 2,520, E_0= 0.01, and E_{max} = 0.99.

Our study demonstrates that modular delivery process design enables the realization of learning effects, as humans improve performance through repeated execution of identical tasks; by designing an identical system and sequentially delivering it, total production costs are reduced (Wright, 1936), while project estimation accuracy increases (Chhetri & Du, 2020). In the modular product system, components can be developed, tested, upgraded, and integrated separately and incrementally, enabling the resilience of infrastructure delivery by allowing for on-the-fly corrections (Baldwin & Clark, 2000; Lammers et al., 2022), and the ability to make such an action is dependent on the harvested capability, which also depends on learning capability. This is a key advantage of modular design, as it enables continuous improvement and adaptation, ensuring that the delivery remains aligned with evolving environmental conditions and technological advancements.

Big and complex deliveries are fragile to SOC (Vazquez et al., 2023). Another key benefit of modular process design is its ability to minimize uncertainty across iterations by breaking large, complex deliveries into smaller, independently manageable deliveries. Each module functions as a self-contained unit that can be developed and refined separately without threatening the entire delivery of technological infrastructure. Since the system to be delivered is smaller, the magnitude of the SOC effect is also small due to the reduced number of connections between activities, which allows for greater delivery resilience. This means that the overrun in one part of the system is less likely to propagate and cause widespread disruptions, thereby reducing the likelihood of extreme overruns, as confirmed by the increase in the decay rate (α) of the power-law distribution, as shown in Table 4.

6. Conclusion

The extent to which a project is completed within the initial time estimation is one of the key elements in project management success. This study advances the discourse on infrastructure delivery by challenging the traditional "quantum leap" approach, characterized by megaprojects, and advocating for a piecemeal, incremental approach known as the iterative-modular approach. From the perspective of system interdependencies, we demonstrate through computer simulation that the SOC phenomenon significantly contributes to the unpredictability of megaproject schedule overruns. The power-law distribution of schedule overruns stems from the fragility of the project activity network in the megaproject delivery model, where a small delay in an activity can cause a big magnitude of overrun (x_{max} = 4.62) across the entire delivery.

In contrast to megaprojects, the classical approach of infrastructure delivery, we show that by breaking down the delivery process into small modules, then delivering them in series and consider the learning mechanism of the delivery organization, the magnitude of overruns is reduced, as well as uncertainty, as explained by a higher decay rate and smaller upper bound in power-law parameters, ruling out the power-law behavior of overrun in infrastructure delivery. By embracing the dynamic nature of the project's environment, our study underscores the importance of adaptability in delivering large-scale technological infrastructure. The iterative-modular approach ensures delivery performance and allows incremental learning to build the project owner's capability, particularly in system integration and in dealing with technological novelty, which is central to trait-making projects.

Our key propositions argue for prioritizing learning from prior experiences, particularly successful experiences, rather than relying on imported expert solutions to cultivate localized expertise to scale up the initial technological infrastructure, and design both the delivery process and infrastructure system architecture in a modular manner to enhance resilience against schedule overrun, as modularity enables learning for growing large. By shifting towards an iterative-modular approach, the outcomes of large-scale technological infrastructure delivery could be more predictable in terms of scheduling, while fostering long-term sustainability in technological advancements.

6.1. Implications for research

Our research paper contributes to the literature on infrastructure delivery by highlighting the roles of a modular delivery process and practice-based learning in minimizing schedule delays, a key part of project management success. This research introduces a linkage between self-organized criticality (SOC) and schedule delays, extending Flyvbjerg et al. (2022)'s work on IT project cost overruns to infrastructure delivery. By demonstrating that modularity and learning can mitigate the power-law behaviors of delays in large-scale technological infrastructure delivery resulting from the megaproject approach, the study provides a framework for modeling project delays through the concept of SOC, which can also be extended to examine and address failures or misperformances in other complex systems deliveries.

Second, our research contributes to the organizational learning in temporary organizations by claiming that large-scale technological infrastructure delivery, a type of trait-making project, should prioritize local capability building over importing expert solutions, as the megaproject approach often overlooks the context of the country where technological infrastructure will be placed, leading to overall inefficiencies in delivery and project failure as the delivered technology and the delivery process fails to adapt to its context. By embedding continuous learning from their previous practices, such as trial-and-error, learning-by-doing, and improvisational learning, countries can build their expertise in developing their own delivery solutions to tackle their specific local contexts (Ika & Donelly, 2017), lowering the degree of exploration of the endeavor (Nyman & Öörni, 2023) and strengthens the argument that knowledge of how to make things is an art, not science (Aristotle, 350 BCE/2009).

Third, we advance the discussion on modular systems in infrastructure delivery by demonstrating how modular process design can overcome the effects of SOC. Unlike the traditional modular approaches, which reduce interdependencies between system components and deliver them in parallel (Baldwin & Clark, 2000; Lammers et al., 2022), we argue that the series modular delivery approach provides identical benefits as the parallel approach in comparison to big one-off delivery, which does not take into account the concept of modularity. We found that series modular delivery can potentially reduce delivery time in the context of trait-making projects where initial knowledge is limited. This discussion of modular systems in infrastructure delivery challenges the economies-of-scale paradigm that underpins the megaproject delivery approach, demonstrating that bigger is not necessarily better because of its fragility to extreme overruns. Our findings support a paradigm shift in infrastructure delivery (Ansar & Flyvbjerg, 2022; Brunet, 2025; Thuesen et al., 2024), advocating for approaches that incorporate the repeatability, adaptability, and learnability of infrastructure delivery processes.

6.2. Implications for practice

This study offers several implications for governments and organizations responsible for delivering large-scale technological infrastructure. By demonstrating the limitations of the traditional megaproject approach and highlighting the roles of modularity and learning in delivering large-scale technological infrastructure, this research provides the following practical insights for initiating such projects.

First, countries should break down infrastructure projects into smaller, sequential modules for deployment, minimizing the cascading effect of delays and isolating errors within individual modules. For example, a smart grid initiative could be rolled out incrementally, district by district, ensuring that failures in delivery in one module do not influence the entire system (Baldwin & Clark, 2000). Moreover, the first iteration enables stakeholders to early identify potential challenges in the delivery process and the impacts of the technological infrastructure in the open environment, which can be further refined in successive rounds of delivery.

Second, when building large-scale technological infrastructure without prior knowledge of such technology, the project owner should institutionalize the knowledge of creating things, which can be achieved through learning-by-doing, trial-and-error, and improvisational learning (Argote & Miron-Spektor, 2011). This can accelerate overall infrastructure delivery and reduce the likelihood of overrun, enabling effective utilization of a strong owner-project governance model. By doing so, the project owner organizations can develop localized system integration capabilities to handle such technology within the country's context without relying on external expertise, thereby promoting the country's long-term sustainability. The path to becoming a strong project owner is not about importing knowledge but about building capabilities throughout the history of the infrastructure manager. This requires deliberate, iterative efforts to harness in-house expertise through hands-on experience with the technology and the delivery process. For instance, UK Network Rail has refined its system integration skills and stakeholder coordination practices over decades, evolving into a megaproject-based firm (Denicol & Davies, 2022). This evolution, in which all parameters in the learning equation are high, enables them to deliver infrastructure effectively through the megaproject approach.

Third, the shift from a static, big-bet megaproject to a modular, learning-driven approach is necessary for the project owner's sustainability. This approach not only mitigates delays and other project management performance measures but also transforms infrastructure projects into vehicles for innovation, trust, and sustainable growth. "The true success of trait-making projects lies not in their physical outputs alone but in their capacity to reshape human capabilities and institutional wisdom" (Hirschman, 1967). However, to achieve this, a new policy or framework for project evaluation is needed that aligns with the nature of phase-based deployment. The traditional framework often favors prestige benefits from megaprojects. We argue that the promised benefits of the megaproject approach are often deceptive, as they are frequently unrealized and frequently calculated by external experts without considering the dynamic nature of the local context. Thus, governments should explore flexible financing and project evaluation structures informed by the outcomes of earlier delivery iterations. This ensures that funds are allocated based on real, perceived benefits rather than long-term projections, which are highly uncertain.

6.3. Limitations and further research

All research is subject to limitations, including ours. First, our analysis relies on theoretical models and prior empirical findings on IT project and megaproject management literature. Future research should explore our propositions through empirical case studies of large-scale technological infrastructure projects that have adopted an iterative-modular approach, such as wind farms or small modular reactors (SMRs). In particular, quantitative data collection on cost and schedule overruns, as well as learning outcomes, could help substantiate our propositions.

Second, the generalizability of the iterative-modular approach may be constrained by industry-specific factors. While our study focuses on large-scale technological infrastructure projects, different sectors may exhibit distinct characteristics that influence the applicability of the iterative-modular approach. Accordingly, exploratory research across multiple industries to examine the boundary conditions of the iterative-modular approach is necessary.

Third, our study does not explore the governance mechanism of the iterative-modular delivery approach. As it is opposite to the traditional megaproject approach, we foresee that the governance mechanism, particularly the role of system integration, needs to be more comprehensive than it currently is. Also, organizational and institutional barriers might hinder the full adoption of our propositions. Future studies should investigate the role of stakeholders in governing our delivery approach.

Fourth, while our findings highlight the benefits of modular design in mitigating the self-organised critical (SOC) phenomenon, further research is needed to determine the optimal degree of modularity for large-scale delivery of technological infrastructure. Excessive fragmentation of the delivery process may introduce inefficiencies, whereas insufficient modularity may leave projects vulnerable to cascading failures. Exploring this tipping point through empirical testing would help to further our understanding of the design and implementation of an iterative-modular approach.

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RESEARCH ARTICLE

Artificial intelligence in agile IT project management: A SWOT analysis

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Abstract
Artificial intelligence (AI) is reshaping agile Information Technology project management by introducing automation and intelligent decision support. This study explores the strategic implications of AI adoption within agile frameworks using a SWOT analysis approach. A systematic literature review of 48 peer-reviewed studies was conducted to identify strengths, weaknesses, opportunities, and threats associated with AI integration in agile environments. The findings reveal that AI significantly enhances sprint planning, backlog prioritization, effort estimation, and software testing; resulting in faster development cycles, improved code quality, and better decision-making. However, these benefits require substantial workflow restructuring, investment in technology, as well as workforce upskilling. Weaknesses and threats are identified, but opportunities for scalable automation and hybrid human-AI collaboration look promising for organizations that adopt AI strategically. The study emphasized the importance of Project Management Technology Quotient (PMTQ) as a critical competency for practitioners navigating AI-augmented workflows. By aligning AI capabilities with agile principles alongside robust governance models, organizations can optimize AI for sustained competitive advantage in the digital project economy.

Keywords
artificial intelligence; agile project management; swot analysis; project management technology quotient; human-AI collaboration.

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1. Introduction

Artificial intelligence (AI) is set to transform project management practice in various aspects, including automation of basic administrative tasks, delivering analytics-driven risk predictions and estimation, facilitating project planning, and making actionable recommendations. In the era of Industry 4.0, companies can take advantage of the efficiencies and transformative power of AI to increase project success rates (Brandas et al., 2023; Fridgeirsson et al., 2023). Because AI-based tools are able to process massive amounts of data from software projects, harvest useful insights, and train to perform complex management tasks, the use of AI can significantly increase the effectiveness of using agile approaches in project management, particularly in the field of information technology (IT) (Taboada et al., 2023). While some might argue that project management and AI are not compatible due to the complexities involved in automating a wide variety of unique projects, new applications are being explored in the field where some aspects can be automated while others will be augmented (Raisch & Krakowski, 2021; Auth et al., 2019). More than sixty percent of project management practitioners believe that they need to learn AI-related skills so they can excel in their positions (Tilo, 2023). Building an organization's Technology Quotient (TQ) alongside the unique nature of the Project Economy is going to be a fundamental shift in the role of the project manager (PMI, 2020). In the project management community, a leader's TQ is their ability to adapt and integrate technological advancements into the needs of their organization or project (PMI, 2019). According to project management professionals, the Project Management Technology Quotient (PMTQ) is the key to an organization's digital sustainability (Taboada et al., 2023). Innovation from project leaders is most likely to stem from those who have higher levels of PMTQ. The types of AI in this systematic review include a range of commonly used AI tools in project management such as Generative AI (i.e., ChatGPT, Copilot, Tabnine), Natural Language Processing (NLP), Machine Learning (ML), Deep Learning (DL), as well as AI-powered chatbots (i.e., Alfred). The choice to include a wide range of AI tools was made to collectively illustrate how both automation and augmentation can enhance agile project management outcomes.

As a framework, Agile project management emphasizes iterative and and incremental development and is now the most used methodology in project management (Krehbiel et al., 2017; Cruz et al., 2020, Kanbur et al., 2023). Contemporary project management practices using agile methodologies seem to produce better quality products and increased productivity (Kassab et al., 2018). The agile approach to project management is gaining traction because of its speedy value delivery and lower risk of project failure (Kanbur et al., 2023). This is attractive to software development teams because agile approaches such as Scrum are grounded on dynamic and iterative environments involving product backlogs, bug fixes, and user stories.

The confluence of AI and agile project management has attracted increasing attention in recent years, especially in the IT sector. While numerous studies have looked at individual benefits of AI in project management (Brandas et al., 2023; Fridgeirsson et al., 2023; Dam et al., 2019) and the effectiveness of agile methodologies in dynamic environments (Cruz et al., 2020; Krehbiel et al., 2017), a research gap in the literature is still notable particularly in their intentional integration. For example, contemporary research focus on technical implementation of AI tools (Choetkiertikul et al., 2019; Esposito et al., 2024; Younisse & Azzeh, 2023) without comprehensively evaluating how these tools influence IT best practices in agile project management. Additionaly, previous SWOT analyses (Brandas et al., 2023) did not tackle characteristics distinct to agile project management as well as the IT industry's unique challenges (Domingues da Silva & Vasconcelos, 2020; Komal et al., 2020).

This study addresses the abovementioned gap in literature by linking technical capabilities and strategic planning, thereby adding to the discourse on AI-augmented agile project management in the IT industry. Specifically, this study aims to (1) assess how AI tools influence agile processes; (2) identify the strengths, weaknesses, opportunities, and threats (SWOT) related to AI adoption in agile IT project environments, and (3) provide practical insights for practitioners and organizations adapting AI into their agile project environments.

2. Related Literature

2.1. Agile project management in information technology

Agile project management relies on iterative and incremental development, as evolving customer requirements and proposed solutions are evaluated and focuses on early software releases and reliance on its software development values of internal and external productive interactions, software delivery, and addressing change (Krehbiel et al., 2017). It is an umbrella term denoting management practices including Scrum, Kanban, and XP, among others (Sankhe et al., 2022). Created in 2001, the Agile Manifesto (Beck et al., 2001) was established to enable software development teams to excel as teams. Agile is now the most used methodology in project management (Cruz et al., 2020). Agile methodology benefits include prioritizing customer requirements, maximizing business value, and a time-boxed approach to software delivery (Holgeid & Jørgensen, 2020).

It has become the cornerstone of IT project management due to its iterative nature, adaptability, and emphasis on collaboration. Among executives, practitioners, and consultants, Agile remains the most common project management approach, with 95% reporting that they utilize Agile development practices and 51% saying that more than half of their teams are Agile (VersionOne, 2020). Agile seems to fare better than traditional methods in terms of benefits (Ameta et al., 2022), but the transition and implementation have been more challenging for project managers (Koi-Akrofi et al., 2019; Locke, 2021). Studies highlight that Agile practices such as Scrum, Kanban, and Extreme Programming (XP) significantly improve operational efficiency, reduce costs, and enhance responsiveness to changing requirements (Reddy, 2025; Appoh et al., 2022).

In a recent study on agile project management approaches and company competitiveness, the significant role of agile leadership and work environment were emphasized as key to successful project implementation (Tominc et al., 2023). Management scholars suggest that an agile project management approach meets the demands of today's market that is characterized by faster product development while allowing quick testing of multiple ideas and responding to real-time feedback from users. When organizations employ an agile approach, they are able to achieve reduced time-to-market and costs and improve user satisfaction with continuous improvements and product updates to improve product-market fit (Paliwal et al., 2024). In software development, agile methodologies allow organizations to quickly deliver a reliable and cost-efficient product (e.g., software). Because it solves the problems posed by the rigidity of a traditional project management approach (i.e., Waterfall), agile software development allows the inclusion of technological changes or customer requirements even in the later stages of development because the product is developed incrementally and iteratively (Ameta et al., 2022). The agile approach has become a staple among software development teams because its methodologies can handle the fast-paced environment of the software development life cycle (Dhruva et al., 2024). Agile frameworks also support cross-functional collaboration and continuous delivery, making them suitable for dynamic IT environments (Al-Herani et al., 2025). Hybrid approaches combining Agile with traditional methods are also becoming more prevalent in large-scale projects challenges (Aniǎć& Bušeliç, 2025).

2.2. Artificial intelligence in agile IT project management

The integration of AI into Agile processes is transforming IT project management. There is a consensus among management scholars that AI, when applied to project management, can increase efficiency and improve success rates (Brandas et al., 2023; Fridgeirsson et al., 2023; Taboada et al., 2023). AI-powered tools such as GitHub Copilot, DeepCode, and generative AI assistants enhance code generation, defect detection, and backlog prioritization, leading to reduced development time and improved code quality (Parvatha, 2023). Large Language Models (LLMs) and multi-agent systems automate sprint planning, user story creation, and testing, while predictive analytics improve risk forecasting and resource allocation (Almalki, 2025). AI also supports decision-making through real-time dashboards, sentiment analysis in retrospectives, and adaptive planning (Elumalai, 2025; Gupta, 2025).

There are significant expectations regarding AI's potential and its application, leading to ongoing debates about whether project managers could be replaced by AI due to its perceived efficiency (Barcaui & Monat, 2023; English, 2023). The rapid integration of AI into project management and software development is reshaping workforce dynamics. Tilo (2023) reports that while up to half of professionals in the field worry that AI adoption within organizations might render their roles obsolete, over 60% recognize the necessity of acquiring AI-related skills to remain competitive and view AI integration as part of broader company reskilling initiatives. In fact, automation and agile project management approaches have been adopted by more than 70% of organizations, in part due to their ability to handle intricacies, hasten the allocation of resources, and make decisions that are backed by data (Saxena & Totaro, 2023). The Project Management Institute (2020) emphasizes that strengthening an organization's ability to adapt to continuous technological advancements (e.g., technology quotient) will be crucial in reshaping the role of project managers within the evolving project economy. Some of the common AI tools used in agile project management are: Aconex, Automated Insights, CA Clarity, Jira, Prometheus, Rally, SpiraPlan, and Workfront (Kanbur et al., 2023). While these technologies enhance efficiency and reduce costs, they also raise concerns about workforce reduction and role redundancy. Studies emphasize that although AI can replace routine and repetitive tasks, human oversight remains critical for strategic decision-making, ethical governance, and creativity (Gupta, 2025).

The market now demands responsiveness (i.e., quick turnaround time) and flexibility. In this sense, organizations need to leverage emerging technologies such as AI and management approaches to prevent current issues in project management from hindering their success in this competitive market (Dhruva et al., 2024). For instance, Generative AI (GenAI) is increasingly becoming a valuable tool particularly among agile project managers as it has the potential to handle common agile pain points by maximizing resource allocations, analyzing large datasets, enhancing collaboration, and automating testing (Bahi et al., 2024). These can provide innovative solutions for complex and dynamic agile environments with iterative development processes. In 2024, a report from Gartner Research estimated that the number of engineering teams that will implement AI-augmented software development will increase by anywhere between 5% to 40% by the year 2027 (Bhat et al., 2024). Other creative AI tools commonly used in agile project managers are ChatBots for daily stand-up, sprint planning, and backlog management; Machine Learning (ML) for work breakdown, risk management, and issue tracking; Natural Language Processing (NLP) for requirements gathering, user feedback, and documentation; Computer Vision for quality assurance, testing, and user experience design; and Collaborative AI for teamwork, communication, and decision-making (Kanbur et al., 2023).

Agile project management approaches can deal with unpredictability and multiple changes that come with software project requirements (Younisse & Azzeh, 2023). Software development is an area that can benefit greatly from the collaboration between AI tools and human creativity and talent, especially during requirements development (Ramasamy et al., 2024). With automation as its greatest strength, project managers can more efficiently break up complex projects with AI tools taking care of documentation and scheduling (e.g., Notion, Motion) as well as summarizing conversations, translating messages in real-time, and encouraging efficient communication (e.g., Slack, Microsoft Teams) (Saxena & Totaro, 2024). The use of AI in software quality assurance has also helped companies cut the time and cost that come with defect discovery and resolution with its ability to help with locating defects, sequence learning, and code cloning among many others (Esposito et al., 2024). Management scholars propose that the future of software development will be shaped by an agile copilot (Hoda et al., 2023), where an AI-based agile team member will leverage machine learning capabilities to provide assistance in project management functions such as project health and effort estimations, decomposition, task breakdown, dependencies refinement, improving backlog grooming, and optimizing test cases. In a recent study on factors affecting successful project implementation, agile leadership, the adoption of AI technologies, and using AI solutions in a project have a significantly positive effect on successful project implementation (Tominc et al., 2023).

Because AI tools can automate many repetitive tasks and generate reports (Barcaui & Monat, 2023), the IT project manager can then focus on strategic decision-making, stakeholder engagement, and resolving critical issues. Just within the framework of Scrum, AI can be used in sprint planning (i.e., prioritization, estimation), daily stand-ups (i.e., AI-assisted tracking and monitoring), epic breakdowns, work breakdown (i.e., dependencies), backlog, and product leadership (i.e., decision-making regarding roadmaps, features, and user experience) (Kanbur et al., 2023). Despite these advancements, challenges persist, including data quality issues, ethical concerns, and resistance to organizational change (Gao et al., 2025; Gupta, 2025). Critics have pointed out that a successful agile execution is questionable because its predictive techniques may not match the scale of large projects that use in-process leading indicators (Ebrahim et al., 2023). While the use of AI particularly in IT project management has plenty of documented advantages, a misunderstanding of what project management entails as well as what AI actually is can lead to project failure (English, 2023). Most project managers tend to "think too big" without a full understanding of what AI can do and how (Schlegel et al., 2023). This can often lead to over-reliance on the technology which consequently creates more risks and vulnerabilities such as when it does not have the attention to detail that comes with a project schedule (Brandas et al., 2023; Barcaui & Monat, 2023).

2.3. SWOT analyses in project management

A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis provides a strategic lens for understanding AI adoption in Agile environments. Successful organizations see the value of strategic management in order to remain competitive. To do this, organizations need to implement strategic management processes. Organizations employ internal and external analyses to build their organizational and competitive strategies. By doing so, organizations can focus on their internal strengths and weaknesses and at the same time identify opportunities and address external threats. As a strategic planning tool, the SWOT analysis is used in various management processes to evaluate how internal and external factors affect an organization's performance. It is one of the oldest and most widely used management strategy and planning tools in the world with its roots in the 1960s during the rise of long-range planning in business (Puyt et al., 2023). Conceptualized in the Stanford Research Institute, the original SWOT analysis commonly referred to as the SOFT approach focused on identifying and discussing what needs to be done to protect the strengths of the organization, pursue new opportunities, fix issues (e.g., faults) within the current operations, and identify and avert future threats (Stewart et al., 1965).

Management scholars have used SWOT analysis to assess how the current trends on AI in project management influence project and management outcomes. Strengths identified through SWOT allow teams to capitalize on existing advantages such as enhanced productivity, automation of repetitive tasks, and improved decision-making enabled by AI-driven analytics (Lourens et al., 2022; Khan et al., 2025). A study on the use of AI tools in project management report that project managers can benefit from AI tools when used specifically for budgeting, information management, project planning, and risk management (Brandas et al., 2023). AI can also be widely implemented to strengthen forecasting and generalizing reports for use in problem-solving (Serban et al., 2020). A survey of project management practitioners similarly indicated that the use of AI has a positive effect on the schedule management plan and scope baseline, cost management estimates, and estimations of resources based on market conditions, resource cost rates, exchange rates, inflation, probability and impact matrix, development of risk management plan, and setting of risk thresholds (Fridgeirsson et al., 2023). Recognizing these strengths allow organizations to align AI capabilities with Agile principles such as accelerated delivery and customer satisfaction. Alternatively, identifying weaknesses such as dependency on high-quality data and integration complexity enables proactive mitigation strategies, such as investing in data governance and upskilling teams (Ricca et al., 2025; Gao et al., 2025).

Organizations that utilize a SWOT analysis can identify areas where AI can extend Agile practices beyond their traditional scope. For instance, leveraging predictive analytics for risk forecasting and fostering hybrid human-AI collaboration for scaling Agile across enterprise environments (Hoda et al., 2023; Bahi et al., 2024) can advance organizational agility and stimulate innovation. Conversely, threats identified through a SWOT analysis can mobilize organizations to develop ethical AI practices and change management strategies. External risks such as security vulnerabilities and workforce displacement can undermine AI adoption efforts (Niederman, 2021; Baidya & Hallur, 2022). When these risks are addressed through strategic governance frameworks, stakeholder trust and compliance increase.

A SWOT analysis can be a powerful tool for evaluating internal strengths and weaknesses alongside external opportunities and threats. It provides a holistic approach to evaluating AI adoption within Agile environments. By systematically assessing strengths, weaknesses, opportunities, and threats, organizations can develop strategies that maximize benefits while minimizing risks, and ensuring that technological innovation aligns with strategic objectives.

3. Methodology

This research is an exploratory effort similar to Brandas et al. (2023), in that it discusses the role of AI in project management. However, unlike the previous study, the aim of this research was to explore how the use of AI particularly in agile project management impacts the success of projects specifically in the field of information technology. No human subjects (e.g., project managers) were directly involved in this research.

3.1. Review protocol

Relevant peer-reviewed papers and conference proceedings within the last five years were reviewed and analyzed using the Systematic Literature Review (SLR) framework. Inclusion criteria focused on peer-reviewed articles published between 2020 and 2025 that addressed AI technologies within Agile frameworks. Data extraction was then conducted to capture project management domains, Agile elements, AI tool used, and SWOT dimensions. Insights from the literature review were then used to assess the strategic strengths, weaknesses, opportunities, and threats of AI adoption in agile IT project management.

3.2. Search strategy and study selection

A comprehensive analysis was conducted using a diverse range of credible data sources including peer-reviewed journal articles, conference papers, and reputable industry reports published from 2020 through 2025. Only materials published in English were included in the review. Articles published in a language other than English were considered only if it has a readily available English version. To be considered for review, articles need to have focused on AI applications in IT project management (i.e., software development, technology administration). Articles that did not directly address these criteria, as well as blogs and opinion pieces, were excluded from consideration.

To identify relevant literature, a comprehensive search across major academic databases (i.e., ProQuest, EBSCO, IEEE Digital Library, AIS Digital Library, ACM Digital Library, Sage, Elsevier, ScienceDirect), as well as through Google Scholar was conducted. A combination of keywords and Boolean phrases were utilized to generate results that included a wide range of studies on AI in IT project management. Some of the search keywords and phrases used included “Artificial Intelligence” and “Project Management,” “AI tools” and “Agile methodology” and “IT projects,” “AI” and “agile” and “software,” “AI” and “risk management” AND “decision-making,” “technology” and “agile” and “project management,” “AI” and “project management” and “SWOT analysis,” “AI efficiency” or “automation” and “Agile development,” and “AI adoption” and “Agile projects” combined with “strengths,” “weaknesses,” “opportunities,” or “threats.”

3.3. Data extraction and synthesis

Titles and abstracts were reviewed for relevance, and full-text articles were assessed to make sure they meet the inclusion requirements. A sample of the AI-Agile coding matrix is presented in Table 1.

Key information from each selected article were extracted, including; publication details, study context, AI technologies utilized, project management domains addressed, and specific SWOT elements included in each study. This coding framework was utilized to ensure a consistent and systematic review for the findings related to each of the four SWOT elements. This coding framework was the foundation for a comprehensive SWOT matrix that was used to assess each study's relevance, which ensured that the final set of included articles were contextually appropriate for the analysis. Table 2 presents a summary of AI technology used in each study included in the analysis.

Table 1. A sampling of the AI-Agile coding matrix

ID	PM Domain	Agile Elements	AI Technology Used	Strength	Weakness	Opportunity	Threat
2	Execution Monitoring Controlling	Behavior-Driven Development (BDD)	GenAI, ML, DL, NLP	Automates repetitive tasks	False positives/ negatives	Enhancing exploratory testing with AI guidance	Privacy risks
3	Execution Monitoring	Agile (general)	NLP, ML	Faster feature development real-time error detection	Setup and integration effort	Integration with CI/CD pipelines, scalable	Resistance to change from team members

Table 2. A sampling of the AI-Agile coding matrix

AI Technology	Referenced Studies
Machine Learning (ML)	Ricca et al., 2025; Parvatha, 2023; Appoh et al., 2022; Pothukuchi et al., 2023; Khan et al., 2025; Lourens et al., 2022; Alam et al., 2025; Gill et al., 2025; Elumalai, 2025; Almalki, 2025; Gupta, 2025; Dhruva et al., 2024; Ramasamy et al., 2024; Ebrahim et al., 2023; Bahi et al., 2024; Baidya & Hallur, 2022; Tominc et al., 2023; Pavličet al., 2024; Velikov & Ivanova, 2025; Hoda et al., 2023; Akpomedaye et al., 2025; Sandoval-Alfaro & Quintero-Meza, 2021; Kruk & Zhukovska, 2025; Al-Herani et al., 2025; Jain & Butler, 2025; Purcarea, 2024; Niederman, 2021; Ranesh et al., 2022; Reddy, 2025; Shahriary et al., 2025; Jayaram et al., 2024; Cinkusz et al., 2025; Zuizuin & Petrenko, 2025; Morozov et al., 2025; Mishra et al., 2023; Nejad et al., 2025; Das et al., 2025; van der Aalst, 2021; Yoshikuni et al., 2024
Deep Learning (DL)	Gao et al., 2025; Ricca et al., 2025; Gill et al., 2025; Ebrahim et al., 2023; Zhao et al., 2025; Hoda et al., 2023; Sandoval-Alfaro & Quintero-Meza, 2021; Kruk & Zhukovska, 2025; Niederman, 2021; Ranesh et al., 2022; Das et al., 2024; Zuizuin & Petrenko, 2025; Varzaru, 2022; Mishra et al., 2023; Nejad et al., 2025; Zaidouni et al., 2024; van der Aalst, 2021; Yoshikuni et al., 2024
Natural Language Processing (NLP)	Gao et al., 2025; Ricca et al., 2025; Parvatha, 2023; Nettur et al., 2025; Pothukuchi et al., 2023; Gill et al., 2025; Elumalai, 2025; Hamza et al., 2025; Almalki, 2025; Gupta, 2025; Dhruva et al., 2024; Ramasamy et al., 2024; Ebrahim et al., 2023; Bahi et al., 2024; Velikov & Ivanova, 2025; Hoda et al., 2023; Kruk & Zhukovska, 2025; Niederman, 2021; Reddy, 2025; Shahriary et a., 2025; Jayaram et al., 2024; Das et al., 2025; Atolagbe-Olaoye, 2025
Generative AI (GenAI)	Ricca et al., 2025; Pothukuchi et al., 2023; Gill et al., 2025; Hamza et al., 2025; Dhruva et al., 2024; Ramasamy et al., 2024; Bahi et al., 2024; Baidya & Hallur, 2022; Tominc et al., 2023; Pavličet al., 2024; Akpomedaye et al., 2025; Kruk & Zhukovska, 2025; Aniďć& Bušelić 2025; Purcarea, 2024; Shahriary et a., 2025; Jayaram et al., 2024; Das et al., 2024; Cinkusz et al., 2025; Morozov et al., 2025
Chatbot	Appoh et al., 2022; Khan et al., 2025; Lourens et al., 2022; Almalki, 2025; Aniďć& Bušelić 2025; Reddy, 2025; Jayaram et al., 2024; Varzaru, 2022; Mishra et al., 2023; Atolagbe-Olaoye, 2025

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3.4. SWOT analysis

One of the aims of this research was to identify the strengths, weaknesses, opportunities, and threats related to AI adoption in agile IT project environments. To address this, the study utilized the SWOT analysis method (Stewart et al., 1965), a well-established, intuitive, and repeatable strategic planning tool. Since the SWOT analysis is a straightforward, repeatable, and instinctive method for exploring the strengths, weaknesses, opportunities, and threats of AI on agile project management (Brandas et al., 2023), using it was a useful strategy to systematically examine the strengths, weaknesses, opportunities, and threats associated with AI integration in agile environments.

As mentioned above, insights from the systematic literature review were used to conduct the SWOT analysis on AI adoption in agile IT project management. Articles that met the inclusion criteria were thematically synthesized and key findings were extracted and coded (see Table 1) into categories aligned with the SWOT framework.

4. Results

A comprehensive search across major academic databases using the abovementioned keywords and phrases resulted in 442 peer-reviewed articles. Each abstract was thoroughly reviewed for relevance, and a total of 165 full-text versions were further reviewed to make sure literature reviews, meta-analyses, studies that did not explicitly look at agile IT project management and an AI implementation were excluded. Fourty-eight studies were included in the final analysis. Figures 1, 2, and 3 show graphical visualizations of all the studies included.

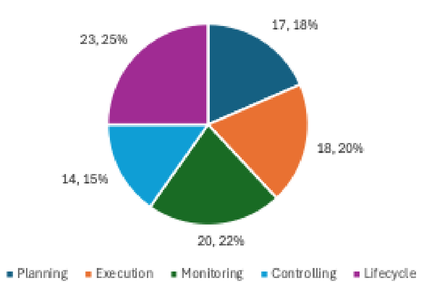

Fig. 1. Distribution of project management domains

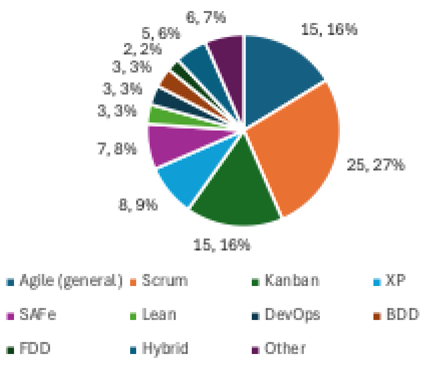

Fig. 2. Distribution of Agile frameworks employed

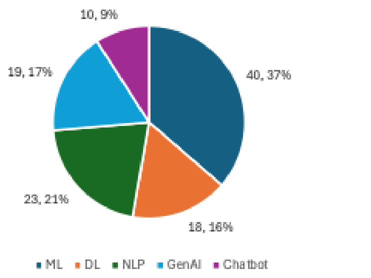

Fig.3. Distribution of AI Technologies utilized

4.1. AI use in Agile project management

Thematic analyses of the peer-reviewed articles included in this study show that IT project managers heavily utilize AI. Some practitioners utilize AI tools throughout the project lifecyle, while some use it only for specific purposes related to a particular project management domain.

The heatmap in Figure 4 presents the proportional relationship between project management domains and AI technologies. It shows how AI adoption is not uniform across domains and that organizations prioritize AI in domains that are heavy in automation and require predictive insights.

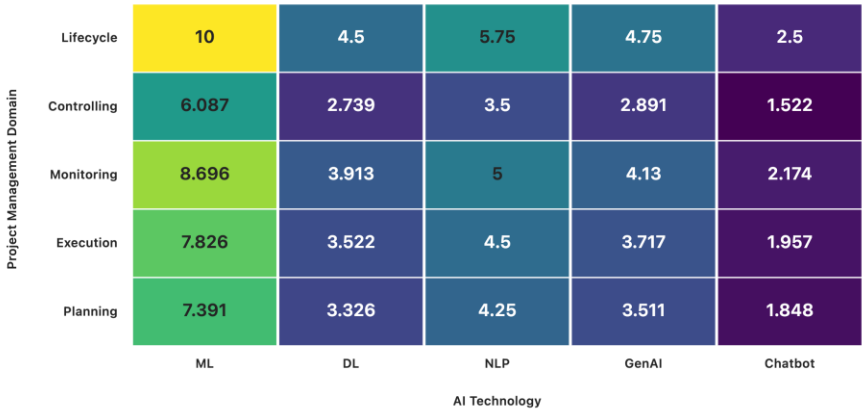

Fig. 4. Heatmap showing project management domains mapped to AI technologies

Machine Learning (ML) is widely used by practitioners during the planning and monitoring phases (Khan et al., 2025; Almalki, 2025). With ML's capabilities for processing historical data and optimization, IT project managers are able to optimize the use of AI in areas such as predictive analytics, resource forecasting, and risk identification.

Natural Language Processing (NLP) and Generative AI (GenAI) are widely popular in the execution phase of IT project management due to their capabilities for automating backlog refinement and generating user stories (Elumalai, 2025; Ramasamy et al., 2024). They are also very efficient in facilitating real-time communication (Ebrahim et al., 2023), and is primarily optimized for continuous communication and support throughout the project.

While not as popular as the other AI tools, project managers have been tapping Deep Learning (DL) in the planning and monitoring phases (Hamza et al., 2023). DL appears to be favored for cost estimation and predictive modeling. Overall, there is low emphasis on Controlling, indicating a gap in AI adoption for compliance and oversight (Tominc et al., 2023; Bahi et al., 2024).

The results of the literature review also showed how project managers adopt AI in various Agile frameworks. The heatmap in Figure 5 illustrates the co-occurrence between Agile frameworks and AI technologies across the studies included in this review.

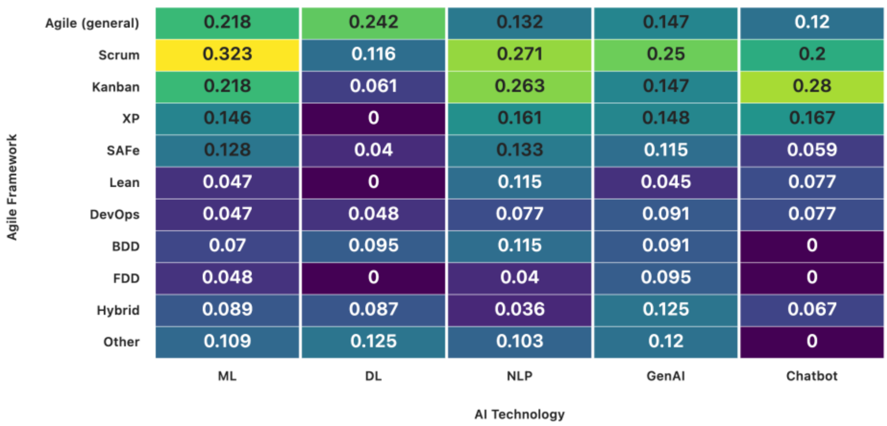

Fig. 5. Heatmap showing Agile frameworks mapped to AI technologies

The heatmap indicates strong integration of Scrum with ML, NLP, and GenAI. Because of Scrum's iterative nature and it's dependence on real-time insights, AI tools integrate well through automating documentation and task breakdown (Pavlič et al., 2024; Purcarea, 2024), as well as improving sprint forecasting, risk prediction, retrospectives, and team sentiment analysis (Elumalai, 2025; Hamza et al., 2025; Shahriary et al., 2025).

ML remains a key player in AI integration in Agile (Gao et al., 2025; Zhao et al., 2025), but NLP and GenAI are gaining more popularity among practitioners NLP and GenAI are increasingly being tapped for capabilities related to communication automation and documentation (Gill, 2025; Hamza et al., 2025). Although not as popular, Chatbots are increasingly adopted into Agile environments to provide real-time support and assistance with backlogs (Appoh et al., 2022; Jayaram et al., 2024).

While Scrum dominates the heatmap, general Agile practices optimize AI for dynamic planning and continuous improvement through ML-driven insights and Gen-AI based content generation (Das et al, 2025; Kruk & Zhukovska, 2025). Although Kanban and XP show moderate co-occurrence, their integration with AI tools is strategic.

Both Kanban and XP integrate AI, particularly with ML and NLP, for automated testing and code reviews (Lourens et al., 2022; Ramasamy et al., 2024). These optimize workflow efficiency and enhance quality assurance through predictive analytics. Scaled Agile frameworks (i.e., SAFe, Lean) have low co-occurrence but are adopting AI (i.e., ML, GenAI) in large scale environments. While not widely adopted, AI is strategically employed for planning and risk management (Cinkusz et al., 2025; Atolagbe-Olaoye, 2025).

4.2. SWOT Analysis

Table 3 presents a summary of the present state of AI in IT project management particularly within the framework of agile methodology. The table illustrates the intrinsic value of AI implementation as well as the potential challenges of AI adoption.

Table 3. Strategic SWOT summary for AI in IT project management

Strengths	Weaknesses	Opportunities	Threats
Enhanced productivity for faster development	Data quality dependence and integration complexity	AI-assisted retrospectives	Ethical concerns, bias, and privacy risks
Improved decision-making and risk forecasting	High computational costs and technical skill requirements	Integration with CI/CD pipelines and DevOps	Security vulnerabilities and compliance challenges
Automation of repetitive tasks and backlog prioritization	Hallucinations, false positive/negatives, and interpretability issues	Scalable automation and hybrid human-AI collaboration	Resistance to change and workforce reduction
Real-time error detection and predictive analytics	Over-reliance on automation and lack of human oversight	Predictive feedback loops	Misuse of AI-generated content and lack of trust
Better collaboration and team alignment		Real-time dashboards	

Agile practices combined with AI can deliver significant benefits that improve efficiency and collaboration across teams. It also opens new possibilities for enhancing Agile practices but presents technical and organizational challenges that can discourage widespread adoption.

As seen in Table 4, these benefits and challenges are very specific to and more optimized when integrated with certain agile practices.

Table 4. SWOT elements linked to Agile practices

<table>
<tr><th></th><th>Strengths</th><th>Weaknesses</th><th>Opportunities</th><th>Threats</th></tr>
<tr><td>Agile (general)</td><td>Increased productivity, improved decision making, enhanced risk forecasting, better collaboration, improved team alignment</td><td>Over-reliance on automation, lack of human oversight</td><td>Predictive feedback loops, real-time dashboards</td><td>Ethical concerns, bias, privacy risks, resistance to changes, workforce reduction</td></tr>
<tr><td>Scrum</td><td>Increased productivity, faster development, automation of repetitive tasks, backlog prioritization</td><td rowspan="2">Data quality dependency, integration complexity</td><td>AI-assisted retrospectives, adaptive planning</td><td>Ethical concerns, bias, privacy risks</td></tr>
<tr><td>Kanban</td><td></td><td>Predictive feedback loops, real-time dashboards</td><td>Ethical concerns, bias, privacy risks</td></tr>
<tr><td>XP</td><td>Real-time error detection, predictive analytics</td><td></td><td>AI-assisted retrospectives, adaptive planning, scalable automation, hybrid human-AI collaboration</td><td>Ethical concerns, bias, privacy risks, security vulnerabilities, compliance challenges</td></tr>
<tr><td>DevOps</td><td>Real-time error detection, predictive analytics</td><td rowspan="2">High-computational cost, high technical skills requirement</td><td>Integration with CI/CD pipelines</td><td>Ethical concerns, bias, privacy risks</td></tr>
<tr><td>SAFe</td><td>better collaboration, improved team alignment</td><td>Integration with CI/CD pipelines, scalable automation, hybrid human-AI collaboration</td><td>Ethical concerns, bias, privacy risks, security vulnerabilities, compliance challenges</td></tr>
<tr><td>BDD</td><td></td><td>Hallucinations, false positives/negatives, interpretability issues</td><td>Scalable automation, adaptive planning</td><td>Ethical concerns, bias, privacy risks, resistance to changes, workforce reduction, misuse of AI-generated content, lack of trust</td></tr>
</table>

5. Discussion

The results of the SWOT analysis presented in this study suggest a shift in IT project management practices, particularly within the Agile framework. The dominance of strengths in areas such as automation, real-time insights, and enhanced decision making suggests that AI can add a cognitive layer for Agile practices. Because AI adoption in Agile is socio-technical, weaknesses such as data quality issues and interpretability challenges are to be expected. AI adoption is not purely technical and, therefore, organizations need to balance AI-human workflows. Organizations must recognize and act on the demands of AI adoption to remain competitive, as implied in the idea of increasing an organization's PMTQ. AI can increase PMTQ by way of real-time sensing and adaptive planning particularly in volatile Agile environments. Ethical AI principles and regulatory compliance must be incorporated into a strategic governance model instead of working from a purely operational framework. This is of notable importance, particularly because stakeholder confidence can erode when quality and accountability are left unchecked.

5.1. AI trends and patterns

Agile IT project managers adopt AI in a domain-specific way, driven by the nature of tasks and data requirements. The trends and patterns illustrated in this study highlight specific AI tools are more useful in one domain of project management than others. For instance, ML is highly adopted during the and execution and monitoring phases because its strength lies in predictive analytics and risk forecasting. Using ML in these project management phases enables teams to anticipate bottlenecks, optimize resource allocation, and improve sprint outcomes (Khan et al., 2025; Almalki, 2025). On the other hand, NLP and GenAI are highly utilized in the planning and execution phases because these technologies enhance collaboration and reduce manual effort by transforming unstructured data into actionable insights (Ramasamy et al., 2024; Bahi et al., 2024). Lifecycle and monitoring phases benefit most from AI due to their reliance on continuous feedback and predictive capabilities, whereas testing remains underutilized. This particular gap implies that AI adoption in this project management domain is budding with opportunities for future research and tool development (Esposito et al., 2024; Yadav, 2023). Lastly, the convergence of multiple AI technologies within the entirety of project management lifecycle emphasizes a growing trend toward hybrid AI solutions that combine automation, analytics, and conversational interfaces to enhance agility and decision-making (Tominc et al., 2023).

5.2. AI Strengths

AI adoption in Agile project management presents several strengths that significantly enhance productivity and project outcomes. Because AI capabilities can accelerate delivery cycles and improve decision-making, teams can focus on innovation rather than manual processes. Automation of repetitive tasks and backlog prioritization, particularly within Scrum, accelerates development cycles and frees teams to focus on higher-value activities (Parvatha, 2023). Generative AI tools assist in backlog refinement, dynamic prioritization, and requirement analysis, shortening product life cycles and improving efficiency (Dhruva et al., 2024; Ramasamy et al., 2024; Bahi et al., 2024). This aligns with Agile's emphasis on adaptability (Khan et al., 2025; Almalki, 2025).

In coding, technologies such as ChatGPT-4, CoPilot, and Tabnine accelerate code generation and completion, improving quality and reducing reliance on manual programming (Bahi et al., 2024). Additionally, AI enhances task creation and management through advanced models like PaLM, which support multilingual processing and automated scheduling. Predictive analytics and real-time error detection, commonly applied in XP and DevOps, enhance decision-making and risk forecasting. Moreover, AI-enabled collaboration tools strengthen team alignment across distributed environments, which in turn reinforces transparency and responsiveness (Lourens et al., 2022). These improvements translate onto lower costs and better deliverables.

5.3. AI Weaknesses

Complexities introduced by AI can potentially slow Agile adoption, particularly because data quality issues can undermine the iterative nature of AI. Experts caution against sharing sensitive data with AI systems due to security risks (Pavličet al., 2024; Bahi et al., 2024). Safety and accuracy remains a top concern as AI tools (i.e., GenAI) often produce inaccurate or biased outputs (Dhruva et al., 2024; Ramasamy et al., 2024; Paliwal et al., 2024). Data quality dependency and integration complexity are critical barriers. Pre-trained models inherit biases from their training datasets, which can manifest during different phases in the lifecycle (Bahi et al., 2024; Pavlič et al., 2024). This is particularly problematic in Scrum and Kanban environments since iterative workflows rely on accurate and timely information (Gao et al., 2025). While AI can reduce development time by up to 75%, outputs still require human oversight to ensure accuracy and contextual relevance

(Paliwal et al., 2024; Bahi et al., 2024). The lack of standardized datasets for training NLP models and the absence of robust validation frameworks in software testing increase the risk of biased or inconsistent results (Younisse & Azzeh, 2023; Esposito et al., 2024). Without reliable baselines, multiple validation pathways can introduce untrained data, leading to variability in test outcomes (Yadav, 2023). High computational costs and specialized skill requirements further complicate adoption in scaled frameworks such as SAFe and DevOps (Ricca et al., 2025). Additionally, interpretability issues and hallucinations in AI models pose concerns related to reliability and accountability (Shahriary et al., 2025). Over-reliance on automation risks diminishing human oversight, contradicting Agile's collaborative ethos (Gupta, 2025). This can eventually erode human judgement, contradicting Agile's collaborative nature.

5.4. AI Opportunities

The opportunities identified in this study emphasize AI's potential as a catalyst for organizational agility and innovation. For example, AI-assisted retrospectives and adaptive planning enhance continuous improvement in Scrum and XP. Robust feedback loops can generate more accurate forecasts and creative solutions, particularly in IT project management contexts (Dhruva et al., 2024). Finetuning also supports the development of standardized regression tests and data validation baselines for software testing, improving reliability and consistency (Esposito et al., 2024). For example, Natural Language Processing (NLP) applications such as N-gram models, Bag of Words, and word embeddings enable better analysis of stakeholder needs and contextual understanding, which in turn improves estimation accuracy and backlog refinement (de Morais, 2021; Younisse & Azzeh, 2023).

Human-centric approaches offer a pathway to sustainable AI adoption. For instance, pair programming allows developers to collaborate with AI assistants. This enables efficiencty without sacrificing human judgment (Dam et al., 2019; Saklamaeva & Pavlič, 2024). Chatbots can provide proactive support during release planning while keeping managerial oversight tight (Ebrahim et al., 2023). AI-assisted retrospectives, adaptive planning, and integration with CI/CD pipelines encourage continuous delivery at scale, while predictive feedback loops and real-time dashboards enhance proactive decision-making across Agile frameworks (Hoda et al., 2023; Bahi et al., 2024; Jain & Butler, 2024).

5.5. AI Threats

The overarching concern suggested in this study is that ethical concerns, security vulnerabilities, and compliance issues threaten trust and transparency (Niederman, 2021). Vulnerabilities in frameworks such as XP and SAFe amplify organizational risk, while misuse of AI-generated content and interpretability issues in BDD contexts exacerbate these challenges (Niederman, 2021; Baidya & Hallur, 2022). Skepticism regarding impact remains prevalent among practitioners, citing the opacity of AI decision-making processes and the lack of mature models for critical tasks such as iteration planning (Paliwal et al., 2024; Saxena & Totaro, 2024; Pavlič et al., 2024). Fears of workforce displacement continue to impede a more widespread adoption (Baidya & Hallur, 2022). Ethical and organizational dilemmas related to job displacement are reflected in these change management concerns (Paliwal et al., 2024; Trufinova et al., 2024). Scholars argue that human creativity and judgment remain indispensable, emphasizing the need for symbiotic collaboration rather than substitution (Kanbur et al., 2023).

6. Implications and Recommendations

The results presented in this study have significant implications for both theory and practice in Agile IT project management. In the era if Industry 4.0, organizations are increasingly navigating workflows that integrate AI and agile frameworks. The results from this study highlight the growing need for exisiting frameworks to refine and extend critical areas.

6.1. Theoretical implications

The use of a systematic literature review combined with SWOT analysis exemplifies methodological innovation by bridging qualitative synthesis with strategic evaluation. It demonstrates the potential for replicable, cross-domain applications of AI-enhanced project evaluation. This study highlights the shift to human-AI collaboration from traditional human-centric models. The strengths and advantages of adopting AI tools in various project management domains and agile frameworks emphasize the role of the project manager as strategic leaders supported by AI-driven decision-making processes (Almalki, 2025; Mishra et al., 2025). AI introduces a paradigm shift in Agile communication models, supporting theories of socio-technical systems where human and machine collaboration co-create value (Ramasamy et al., 2024; Bahi et al., 2024).

The vital competency that the concept of PMTQ brings into the fast evolving landscape of information technology suggests that Agile theory must evolve to incorporate data-driven decision-making as a core principle, rather than a supplementary practice. This aligns with emerging perspectives on hybrid intelligence, which emphasize the complementarity of human creativity and machine efficiency (Wilson & Daugherty, 2018). The growing trend toward hybrid AI solutions point to the need for theoretical models that account for multi-modal AI environments. The convergence of multiple AI tools with project management domains calls for a more comprehensive theory of AI-enabled agility (Tominc et al., 2023).

The use of SWOT also introduces strategic anticipation into agile environments. Ethical concerns such as job displacement and trust in AI systems prompt theoretical inquiry into change management and technology acceptance (Gill, 2025; Al-Herani et al., 2025). This theoretical gap in governance and ethics within Agile frameworks necessitates an extension of Agile theory to include ethical AI principles and governance structures (Gao et al., 2025; Niederman, 2021) to strengthen adaptability in environments where automation and compliance intersect.

6.2. Practical implications and industry recommendations

The findings of this study suggest that AI integration into agile IT project management is strategically advantageous. The results imply that AI facilitates agile IT efficiency and innovation. AI is capable of supporting faster development cycles, improved code quality, more informed decision-making, better software quality, and increased deployment efficiency. This, however, comes with significant workflow restructuring, investment in technology, and considerable upskilling. As AI augments core agile practices, project managers are to shift from operational roles to a more strategic leadership capacity. This shift aligns with the evolving expectations of PMTQ, or the ability to integrate and adapt to emerging technologies in project environments (PMI, 2020; Mishra et al., 2025).

With the industry-specific challenges highlighted in this study, it is imperative for organizations to invest in ethical AI and cost-effective infrastructure to counter bias, data validation challenges, and fears of displacement amongst the workforce. Organizations need to be strategic in investing in robust governance frameworks and change management strategies (Gao et al., 2025; Gill, 2025). Instead of replacing human roles with insightful deliberation, AI should augment IT professionals' capabilities. Organizations that prioritize PMTQ development (i.e., reskilling initiatives) and implement transparent adoption policies will be better positioned to leverage AI for continuous improvement and competitive advantage in the digital project economy (Tominc et al., 2023; Bahi et al., 2024).

These practical implications can lead to actionable strategies that organizations can implement. The results of the study consistently highlight the need to begin prioritizing PMTQ development by way of reskilling initiatives (i.e., training programs). For instance, companies can sponsor AI literacy workshops and certifications for project managers so that they can be effective when using tools like GitHub, Copilot and Jira. Organizations should also consider adopting AI strategically across agile phases, focusing on phases where a specific AI technology can be most impactful (i.e., NLP for backlog refinement and user story generation). Additionally, companies should establish compliance frameworks to implement ethical AI governance. For example, deploying explainable AI dashboards (i..e, decision paths) to monitor algorithmic decisions can address bias and privacy risks. It is also important for organizations to promote AI-human collaboration rather than push for full automation. Pairing developers with AI assitants during code reviews is an excellent example of under-reliance to AI while ensuring appropriate human oversight. Lastly, business need to invest in cost-effective infrastructure and powerful data validation systems (i.e., AWS, Azure) to provide secure environments for AI-driven pipelines. Using cloud-based platforms reduce integration complexity while still maintaining security.

7. Limitations, Future Directions, and Conclusion

This study's SWOT framework provides a general overview of AI adoption in Agile IT project management. While a SWOT analysis is a powerful strategic planning tool, it does not quantify the impact of each factor. When factors are treated as equally significant in their impact, the results can lead to a strategic misalignment. For example, task automation might be labeled as a top priority because of its high-value, low-risk nature. However, task automation might not be the best tool to implement if the scenario calls for stakeholder and relationship management (i.e., client relationship building, mediating conflicts). Additionally, a SWOT analysis' static perspective in a rapidly evolving digital environment limits it long-term relevance. As AI technologies mature, what are identified as weaknesses and threats now might diminish while new risks arise. External industry factors and interdependencies were not included in this study, limiting the scope of its generalizability.

These limitations can be addressed in future research by utilizing a weighted SWOT matrix. This assigns numerical values based on impact and feasibility. Another future direction would be to integrate SWOT with PESTEL analysis. This will allow scholars and practitioners to account for external factors and contingencies (i.e., economic conditions, IT regulations) that influence AI adoption. Additionally, a TOWS matrix can be used to link external factors with external opportunities and threats, which in turn creates an adaptive decision-making framework for practitioners. Lastly, empirical studies and longitudinal research can provide more insight in terms impact validation on areas such as project success metrics and team dynamics.

This study provides critical insights into the strengths, weaknesses, opportunities, and threats of AI integration in agile IT project management. The findings underscore AI's ability to enhance effort estimation, task automation, and software testing, among others. While these domains can significantly enhance project efficiency and responsiveness, challenges require strategic mitigation techniques. Mitigation efforts through governance and oversight can address bias and accuracy issues, as well as confront high computational costs. Opportunities directed towards increased PMTQ and hybrid human-AI collaboration are promising, but threats such as job displacement and compliance risks must be strategically and proactively managed. In this digital economy, organizations can forge ahead and move beyond traditional agile workflows using evidence-based strategies that optimize AI.

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RESEARCH ARTICLE

Understanding, experiencing, and applying Agile project management techniques: A scaffolded higher education assessment framework

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Abstract

Through the tight integration of industry needs and Agile project management education, higher education institutions, and business organisations can help to foster a workforce that is prepared for the dynamic, iterative, and collaborative modern business. Industries are seeking professionals who not only understand Agile project management techniques but can also respond to customer needs, effectively collaborate, and communicate, and adapt to change through experience and application. The assessment of Agile project management in higher education should therefore include these critical skills to meet the job market's current requirements. This paper discusses a case study of a UK based university to show how students were exposed to industry expertise and experience, real-world challenges, and Agile project management tools and methodologies as a way of encouraging active engagement and equipping them for the dynamic workplace. A scaffolded assessment approach was taken to encourage engagement, deep learning, and skills development.

Keywords

agile project management; student engagement; scaffolding; agile pedagogy; soft systems methodology.

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1. Introduction

Organisations across different industries are adopting Agile principles to enhance flexibility, adaptability, and efficiency (e.g., Lekatsas, 2024). Agile methodologies like Scrum and Kanban tend to be the preferred frameworks for managing projects, especially in technology-driven companies. Roles such as Project Managers, Scrum Masters, and Product Owners often require a solid understanding of Agile. Today's employers value employees who can adapt to change, respond to evolving customer needs, thrive in fast-moving environments, and undertake iterative complex problem-solving (Harvard Business Review, 2019). As industries increasingly adopt Agile methodologies for project management (PM) and product development, possessing Agile skills can significantly boost a candidate's job prospects. Gartner (2023) notes that organisations report a skills gap when transitioning to Agile product development, with building skills the second most common action (after hiring) used to close the skills gap. Furthermore, the importance of higher education students learning skills for employment has long been positively advocated (e.g., McKinsey & Company, 2019). Indeed, employability skills have now become a key component of degree programmes (Cole & Tibby, 2013).

The linking of industry with teaching Agile can help to provide a tight connection between the academic environment and real-world business needs. Strong industry-academic partnerships by universities can help to support student growth, better prepare students for success in the job market and provide a strong and more solid foundation on which to continue to learn and grow professionally compared to some other approaches (Hoteit et al., 2023). This can help students to acquire practical skills that are directly applicable to their future careers and ensure that industries benefit from a workforce that can adapt to modern work methodologies. Moreover, the active engagement of undergraduate students is a complex challenge but one that holds the key to successful academic outcomes. Links with industry and academia can help to foster a sense of active engagement amongst students.

Student knowledge and understanding of Agile practices at the earlier stages of undergraduate study can be elementary. As Bloom (1956) mentions in his taxonomy, students develop skills based on their level of study (e.g., level 4 - first year undergraduate). Bloom's Taxonomy emphasizes higher-order thinking: analysis, evaluation, and creation. These levels foster independent learning, research capability, and innovation, essential for tackling complex, real-world problems beyond rote memorization. For example, enabling students to critically examine concepts, justify decisions with evidence, and synthesize ideas to produce original work.

With experiential and problem-based learning Agile project management skills can be developed through the course of a degree programme, in order to equip students and serve industry needs. Assessment in higher education provides the means for students to know themselves as future professionals (Nieminen & Yang, 2023). Freire (1984) argued that any pedagogy must enable students to analyse, theorise, and intellectually engage with the worlds that are relevant to the immediate worlds of the students. More recently, Rutherford et al. (2024) points out that there is a need for assessments to be meaningful, engaging, well-integrated into learning activities, and student-focused in order for them to effectively support learning.

This research uses scaffolding (Bruner, 1966) as a way of providing a temporary framework of supportive elements in Agile project management assessments to help students develop a higher level of understanding. The assessments aim to be engaging, integrated into the learning, and relate to the 'world' that is relevant to students in a professional context. Authentically emulating a given environment or challenge, makes them meaningful and transferable beyond the classroom environment. This can enable a deep learning experience for the student (Smith & Johnson, 2020) together with student engagement (Berry & Kowal, 2022).

This paper discusses ways in which students Agile project management understanding, experience and skills application can be strengthened through a scaffolded assessment framework. This research focuses on the perspective of a United Kingdom (UK) based case study through examples of two years of undergraduate university study and a work placement year. It details the mutually beneficial industry and academic links together with the techniques used to scaffold assessments to enhance student engagement, deep learning, and skills development.

This study advances Agile pedagogy and scaffolded learning by showing how structured, multi-year assessments enhance engagement, deepen learning, and improve employability through authentic, industry-linked experiences, and progressive application of theoretical frameworks.

The remainder of the paper is organised as follows; section 2 discusses literature in relation to scaffolding, student engagement, group work, industry involvement, and Agile project management teaching and assessment techniques; section 3 focuses on the case study and assessment framework; section 4 shows the evaluations given by students of their learning experiences, and conclusions are drawn in the final section.

2. Background

2.1. Student engagement

Research into student engagement in higher education shows its importance for academic success and personal development. In particular the engagement of students in academic study has been found to have a positive relationship with employability skills (Towl & Senior, 2010) and higher-level earnings (Walker & Zhu, 2013). Specific studies (e.g., Mebert et al., 2020) have shown that student engagement can be fostered through real-world, collaborative projects improving student learning and enhancing a sense of empowerment.

Freeman et al. (2014) conducted a meta-analysis that found active learning improves both engagement and academic performance compared to traditional lecture-based instruction. This is because students are more involved in the learning process, requiring them to apply and analyse concepts. Trowler (2010) found that students who actively participate in class discussions, engage in peer learning, and interact with tutors are more likely to report higher engagement. Research by Umbach and Wawrzynski (2005) shows the significant impact that tutor behaviour can have on student engagement. They found that tutors who actively involve students in learning, provide timely feedback, and create a supportive learning environment can have a positive influence on student engagement. When tutors are approachable and encourage critical thinking, students are more likely to be engaged. Furthermore recent findings show agile environments require continual benefits and evaluation across iterative cycles (Delisle, 2025).

2.2. Classroom dynamics

Classroom dynamics that foster participation, like asking open-ended questions and encouraging group work, positively influence engagement levels. Group-based learning has long been successfully used for deep learning at all levels of education providing a way of enhancing communication skills, encouraging active participation, collaboration, knowledge-sharing, and developing social skills (e.g., Hurst et al., 2013; Scager et al., 2016). Additionally, group-based learning has been shown to assist with motivation (Gillies, 2003) and promote academic achievement (Gillies & Boyle, 2011). Recent research further shows that team work quality can be measured and predicted using well established behavioural indicators reinforcing the importance of collaborative learning (Behn & Silvius, 2025). Furthermore, being able to work efficiently with others is considered one of the critical skills demanded by employers once graduates begin work. Johnson et al. (2007) notes that higher education institutions are increasingly using collaborative learning groups in order to equip students with teamwork skills, which are highly valued in the professional world.

Lutchen (2024) highlights the value of university-industry partnerships in ensuring that students acquire job-ready skills, and the importance of an ongoing and sustainable partnership which can provide real-time input on the critical technological skills students will need in their careers. "Students with industry-linked educational experiences are more likely to transition smoothly into the workforce, making them highly attractive to employers" (NACE, 2020). Industry collaborations with academic institutions provide fresh insights and perspectives enabling companies to generate innovative services, products, and processes (Bamford, 2024).

2.3. Scaffolding

Scaffolding, as an instructional strategy, originates from the work of Bruner (1966) and is closely aligned with Vygotsky's (1978) concept of the Zone of Proximal Development (ZPD). It refers to the temporary support provided by educators, peers, or tools that enables learners to perform tasks they would not be able to accomplish independently. As learners gain competence, this support is gradually withdrawn, promoting autonomy and mastery.

In the context of higher education, scaffolding is particularly effective in supporting diverse learning styles and fostering deep learning (Salend, 2001; Murtagh & Webster, 2010) potentially leading to improved academic achievement. It allows educators to structure learning experiences that are both challenging and achievable, thereby enhancing student motivation and engagement. Kang et al. (2014) identified five types of scaffolding that significantly improve student reasoning and explanation quality: contextualized phenomena, rubrics, checklists, sentence frames, and explanatory models. Among these, contextualized phenomena real-world scenarios embedded in assessments had the most substantial impact.

Scaffolding is not limited to instructional delivery but extends to assessment design. Scaffolded assessments provide students with clear expectations, continuous feedback, and opportunities for reflection and revision. This approach aligns with Ambrose et al.'s (2010) principles of effective learning, which emphasize timely, targeted feedback and the importance of making learning goals explicit. Moreover, scaffolding can be enhanced through peer interaction, where students co-construct knowledge and support each other's learning (Howe, 2013).

In Agile project management education, scaffolding plays a critical role in bridging theoretical knowledge with practical application. The scaffolded assessment framework described in this study spanning understanding, experiencing, and applying demonstrates how structured support across academic years can lead to improved student engagement, deeper learning, and enhanced employability skills. By integrating industry challenges, iterative feedback, and collaborative learning, the framework enables Agile principles to be taught in a supportive way and prepares students for real-world project environments.

However, as Stanier (2015) notes, the effectiveness of scaffolding depends on its alignment with learner needs and the gradual fading of support. If scaffolds are removed prematurely or inconsistently, student performance and engagement may decline. Therefore, a consistent and well-communicated scaffolding strategy across modules and academic years is essential for sustained learning outcomes.

2.4. Agile in learning and teaching

Agile has been successfully integrated into higher education curriculums using a number of different techniques. For example, Lego4Scrum (Krivitsky, 2019) is an experiential learning activity that introduces Scrum practices using Lego blocks. Learners simulate a Scrum process by building a city out of Lego over several Sprints, experiencing the roles of Product Owner, Scrum Master, and Development Team. This has proved effective in helping students understand Agile principles and team collaboration. Emerging technologies such as meta verse environments offer additional avenues for immersive project management education (Ozsoy, 2025). The Planning Poker game has been used to teach students how to estimate work tasks in a collaborative way, helping students to break down user stories, estimate their complexity and collaboratively agree on task sizes (e.g., Buchem et al. (2023); Mahnic & Hovelja (2012)).

Combining online learning modules with in-person workshops focused on Agile certifications, such as ScrumMaster helps prepare students for industry-standard qualifications. A study at Purdue University (2021) shows that this led to significant improvement in Agile certification outcomes. The flipped classroom technique where students learn theory outside of class through videos, readings, and exercises and then apply Agile practices like sprint planning, retrospectives, and collaboration activities in class has also been shown to be effective (Schwaber & Sutherland, 2020) and could result in more engaged students and deeper understanding of complex Agile concepts. Agile hackathons, time-constrained events where students use Agile methodologies to quickly prototype and develop solutions, has been shown to enhance student's ability to iterate quickly and deliver tangible results (Afshar et al., 2022).

Collaborating with industry partners has been effective in allowing students to work on real-world projects using Agile methodologies. "To encourage academia-industry collaboration, business schools must equip students with Agile thinking and inclusivity skills to align with workforce needs" (Haynes, 2024). A study by Boti et al. (2021) at the Hellenic Open University showed that the implementation of Agile methods can benefit project team members and help them develop both their transversal skills and team working characteristics. This paper will share the experiential accounts on the delivery of an Agile module and its structured assessments to second year undergraduate students.

2.5. Agile beyond software: Broader applications across industries and higher education

Although Agile project management (APM) originated in the software development sector, its core principles of flexibility, iterative progress, customer collaboration, and responsiveness to change have proven valuable across a wide range of industries. As organisations face increasingly dynamic and complex environments, Agile has emerged as a viable alternative to traditional project management approaches in sectors such as manufacturing, construction, telecommunications, and education.

A systematic literature review by Noleto et al. (2023) identified three primary ways Agile is being adapted outside of IT: (1) planning-focused applications, (2) use within support areas of organisations, and (3) selective adoption of Agile practices without full structural change. For instance, in manufacturing, Agile is often applied during the design and planning stages to enhance flexibility and responsiveness before production begins. In construction, Agile has been used in contract management and procurement processes to improve adaptability and stakeholder communication.

These adaptations are not about replicating Agile in its purest form but about tailoring its principles to fit the unique constraints and workflows of different industries. This hybridisation allows organisations to benefit from Agile's strengths such as rapid feedback loops, stakeholder engagement, and iterative development without overhauling their entire operational structure (Noleto et al., 2023).

The appeal of Agile in non-software contexts lies in its ability to address common project challenges, such as scope creep, misaligned stakeholder expectations, and the need for innovation under uncertainty. For example, Agile-stage-gate hybrids have been used in product development to combine the structured decision-making of stage-gate models with the flexibility of Agile practices, resulting in faster time-to-market and improved product quality (Noleto et al., 2023). As Agile continues to evolve, its cross-sector adoption reinforces its versatility as a project management philosophy rather than a rigid methodology. This broader application aligns with higher education institutions goals which aim to equip students with transferable, industry-relevant skills that extend beyond the boundaries of software development.

The integration of Agile project management (APM) into higher education (HE) reflects a broader shift in pedagogical approaches that aim to align academic learning with the dynamic needs of the modern workforce. As HE institutions face increasing pressure to produce work-ready graduates, Agile offers a framework that supports experiential, student-centred, and industry-relevant learning. Agile principles such as iterative development, responsiveness to change, collaboration, and continuous feedback resonate with contemporary educational theories including constructivism, experiential learning, and active learning. These principles support the development of critical employability skills such as adaptability, communication, teamwork, and problem-solving. In this way, Agile is not only a project management methodology but also a pedagogical paradigm that fosters deep learning and student engagement.

Despite its benefits, integrating Agile into HE presents challenges. These include the need for staff development, curriculum redesign, and assessment innovation (Fitsilis et al., 2023; Dazeley et al., 2024). Woods and Hulshult (2025) highlight that students may face difficulties stemming from the unpredictability of real client interactions and their unfamiliarity with Agile, which can lead to resistance. Such challenges mirror real world project environment where misalignment between tools and stakeholder needs can hinder progress (Rankinen, 2025). A study by Pombo and Cunha (2025) that examined the effectiveness of teaching Scrum principles found that some students improved communication and teamwork skills whilst challenges included steep learning curves, uneven engagement, and tech limitations. Institutions must therefore invest in change management and provide adequate support to ensure successful implementation (Ionescu & Bolcas, 2018).

As HE continues to evolve in response to technological, economic, and societal changes, Agile is likely to play an increasingly prominent role. Emerging trends such as hybrid learning, micro-credentials, and interdisciplinary project-based learning create favourable conditions for Agile methodologies. Furthermore, the growing use of AI and digital tools in education can enhance Agile practices, enabling more personalised and data-informed learning experiences. Recent studies highlight how data driven insights can further enhance organizational agility by mitigating risks and disruptions (Barhmi & Laghzaoui, 2025).

In summary, Agile project management offers a powerful framework for reimagining teaching, learning, and assessment in higher education. Its broader adoption can help institutions better prepare students for the complexities of the modern workplace while fostering a more engaging and responsive educational environment.

2.6. Placement learning experience

Research into the experiences of students on traditional work based placements is extensive. A study by Juznic and Pymm (2011) suggests that students returning to university from their placement year agreed that their time on placement has led to a positive experience. However, the findings also supported the fact that it tends to be the more capable and diligent students who go on placements. Students with work placement experience, consistently obtained better academic marks than those who had not. The study confirms other findings that an extended work placement enhances the prospect of a good degree and graduate employment. Other research (Bennett et al, 2008) suggests employers continue to regard formal work placements favorably, and that they point out their usefulness for developing several critical employability skills. These include developing interpersonal and leadership skills, tolerance of others, and skills relating to conflict resolution and negotiation. The benefits that students can gain from work placement include increased employability and better academic achievements (Ceschin et al., 2017).

A study by Brookes and Youngson (2016) found that completing a work placement is associated with improved academic performance in the final year of study. Placement students are also more likely to secure appropriate graduate-level work and higher starting salaries upon completion of their degree in comparison to non-placement students. Demonstrating the impact of a work placement by academics could help students to make informed decisions on whether to undertake one, potentially increasing participation rates. Studies (e.g., Smith et al., 2019) also suggest that the placement experience is a better predictor of a variety of employability outcomes than either structure of the placement experience or the duration of the placement.

The experiences of the students in a study by Smith et al. (2007) show that reflection appears to showcase the technical skills learnt during their placement experience. The reflection of the placement experience makes the journey more authentic. Being in a work placement environment allows for the refinement of prioritization skills and personal transferable skills (Poulter & Smith, 2006). However, placements do have some disadvantages including the competitive nature of obtaining placements. In summary, research has found that the placement experience and development of transferable skills is relevant for the final year of study and graduate employment. The advantage of having a placement outweighs the disadvantages. To encourage students to obtain a placement, academics need to share these benefits and communicate them to the students.

2.7. Consultancy SSM application

Soft Systems Methodology (SSM) can be used to understand complex ambiguous problems in the classroom. Research has shown that SSM and interdisciplinary approaches have not been readily adopted by academia or business schools (Cezarino et al., 2016). The SSM pedagogical approach can cross disciplines from systems thinking to business management. This paper will share the practical accounts on the delivery of the methodology. A final year taught module will be used to understand PM and SSM and the scaffolded aspects of the assessment will be discussed. Checkland and Scholes (1999) states that any intervention should consider the views of all stakeholders and the solution must come from the people involved in the problem situation. Being empathetic to the stakeholders in the problem situation enriches the SSM approach further.

SSM, has been developed by Peter Checkland in the 1970s (Checkland & Poulter, 2006). It is designed to address complex, poorly defined problems, especially in social settings (Nair, 2015). Unlike hard systems methodologies, which rely on quantitative data and assume systems operate in predictable ways, Soft Systems Methodology (SSM) acknowledges the complexity and uncertainty inherent in human systems (Wilson, 2001). Recognizing the significance of meaning in social interactions is crucial, as it influences how individuals communicate, build relationships, and make decisions (Armstrong, 2019).

Preliminary insights from teaching SSM suggest that adopting an empathetic Agile project management approach helps participants grasp both the methodology and the complexity of the situation more effectively than relying solely on theory. Agile practices support deeper understanding, while collaborative group work further strengthens this and enables practical application within the project context.

2.8. Summary

This literature review shows that several different techniques have been successful for teaching Project Management. The first being Agile project management techniques. This is followed up by actual hands on project management during student's placement experience. The third being stakeholder project management through the use of SSM. They tightly link industry and academia in Project Management which has been shown to have a positive effect on student engagement and provide students with critical industry skills. Using groupwork can also help to foster student engagement and enhance valuable industry competencies. The case study that follows combines a number of such techniques for the teaching of a second year undergraduate Agile Project Management module followed by a placement module, then a final year consultancy module using SSM project management.

3. Design and development of scaffolded assessment framework

The framework used for assessment scaffolding was three-fold (Fig. 1). The three core aspects – understanding, experience and application were taken from Bloom's taxonomy (1956) and aimed to increase students subject area knowledge and understanding together with engagement, and skills development as they progressed through undergraduate study.

Understanding was developed in year 2 of undergraduate study through a module that focused on Agile concepts and involved building a prototype for a real-world challenge. Experience was gained in the third year of study through a work placement year and associated assessment and application of learning was achieved through a module that focused on a fundraising challenge. The final-year module assessment is based on peer review and an independent reflection. This form of assessment is supported by previous learning journeys from the second year and the placement year. Having experienced scaffolded learning, teaching and assessment in previous years students are more amenable to the same approach to assessment in the final year. Understanding agile PM perspectives in year 2 and experiencing them in the real world in the placement year allows students to apply this learning in the final year. This then naturally feeds into engaging with PM needs in employment post University. This learning journey over the three years has led to students' attainment being much better than before the scaffolded approach.

UNDERSTANDING | Year 2 undergraduate

- **ASSESSMENT**
- Assessment 1 - Group work project presentation
- Assessment 2 - Individual log book

- **SCAFFOLDED ENGAGEMENT ELEMENTS**
- Core Agile project management concepts - classroom and online
- Real world industry set assessment challenges
- Hands on use of Agile project management tools and techniques
- Allocation of group work tasks and building up of project as the module progresses
- Tutor, peer and industry feedback on progress
- Industry guest lecture
- Prizes for best performing students for group work
- Structured grading matrix with suggestions of components for each element

EXPERIENCING | Work placement year

- **ASSESSMENT**
- Assessment 1 - Project presentation
- Assessment 2 - Individual reflection

- **SCAFFOLDED ENGAGEMENT ELEMENTS**
- Real world work placement experience
- Investigation of real world work placement challenge for assessment project presentation
- University tutor and industry manager feedback through regular meetings
- Project proposal form completed by student and agreed by tutor
- Ethical approval form completed by student and agreed by tutor for data collection for project presentation

APPLYING | Final year

- **ASSESSMENT**
- Assessment 1 - Group work, creativity, amount raised and peer review
- Assessment 2 - Individual reflection

- **SCAFFOLDED ENGAGEMENT ELEMENTS**
- Charity fundraising event
- Peer review and independent reflection
- Soft systems used to design event using empathetic discourse
- Teammates used to scaffold peer reviews
- Reflection marked by authenticity, specificity and critical analysis
- Reflection designed around critical incidents during fundraising event

Fig. 1. Scaffolded assessment framework for Agile project management engagement

The Case Study section in this paper explores each of the three elements of the framework for engaging students in Agile project management. The scaffolded approach to the design and delivery of the modules helped engage the students with the theory and practical perspective. The scaffolded approach to teaching, learning and assessment is conducive to deep learning and can lead to improved academic achievement. Consideration does however need to be given to how and why particular modes of assessment are used to assess student achievement (Murtagh & Webster, 2010). Feedback from students prior to the scaffolded approach suggested that they were not engaging with the theory of Agile project management and Soft Systems and relating it back to their learning journey. The links between theory and project management in real-world scenarios needed to be clarified and linked to the module learning outcomes. Once students can see the relevance of the theory, they are more likely to incorporate it into their learning journey.

There does need to be a balance between the scaffolded approach and the independent learning of the student. Scaffolding should support the student but not replace the independent learning journey. This balance will be based on experiential teaching and learning and student attainment in formative and summative assessment. The support should help students engage with the module content and still promote independent thought and analysis. This will allow students to apply their learning to the real world where the scaffolded approach will not be apparent.

Scaffolds may be described as strong, where they provide a large amount of guidance and support for the learner, where the support is less (Stanier, 2015). This study suggests that the scaffolding approach provided good support for the initial exploration of the material but there were issues around the removal of scaffolds. This was due to the mismatch between the student and tutor expectations of the scaffolds. If scaffolds linked to assessment are removed then the experience of students also drops, and attainment is less. The scaffolded approach therefore needs to be consistent across modules and between academic years. This paper demonstrates this scaffolded PM approach works across three years of academic study.

4. Case study

This case study focuses on learning, teaching and assessment at the triple accredited (AACSB, AMBA and EQUIS) Aston University Business School in the United Kingdom. Aston University Business School is one of the UK's leading business schools and has been a pioneer in embedding industry connections and the work placement programme within undergraduate study. All undergraduate courses have a mandatory work placement element and industry links throughout module diets. It also provides support for small and medium enterprises and staff pioneer innovative teaching methods to make the student learning experience rewarding, engaging, and enable students to experience real-life business through projects. The next three sub-sections will outline more details about the modules at each level of study.

4.1. Understanding – Agile module

The Agile module is a second-year (level 5) undergraduate module and is mandatory in the Business Computing and IT degree course. Students on some other courses, such as Business Analytics and Business and Management, can also optionally select to study the module. It is studied over 11 weeks. The module learning outcomes include analysing information systems from both user experience and information needs perspectives; developing and communicating solutions through iterative, collaborative problem-solving in Agile teams, and applying Agile project management techniques to plan, manage, and deliver projects.

The Agile teaching curriculum was fundamentally designed in collaboration with industry professionals so that it reflected the latest practices, tools, and challenges that organisations face. The industry experts had previously studied for their MBA at Aston, had many years of experience in the field and set up a small business through the Aston Help to Grow scheme (a 12-week program that helps senior managers of small and medium-sized businesses improve their performance, resilience, and long-term growth).

The depth of technical and theoretical content in the module could be adapted to the audience based on the experience level of the learners. Teaching started with Agile fundamentals – what is Agile and why Agile. This helped to highlight how Agile addresses issues like changing requirements, the need for frequent client feedback, shorter time-to-market cycles, and improving team collaboration. Different frameworks were introduced to students such as Scrum and Kanban. Key practices were taught such as requirements elicitation, user stories, backlog prioritisation, and the concept of a sprint. Other aspects such as systems modelling, prototype development, and testing were also integrated into the module together with project scheduling, tracking, and planning. Video lectures were used to provide students with background knowledge and concepts reviewed in lecture sessions.

The teaching of Agile included tools commonly used in industry such as Slack for collaboration and communication, Jira, and Trello for backlog management, sprint planning, and tracking progress. Familiarity with these tools can give learners a competitive edge when entering the job market, as many Agile teams depend on them to manage projects and collaborate. Prototyping tools such as InVision and OnShape were also included as resources on the module. Students were also encouraged to research other tools and use these within their projects. The importance of selecting appropriate cloud-based project management tools is well recognized industry, where successful adoption depends on a number of critical success factors (Assalaarachichi, 2025).

The industry experts were invited to set the assessment challenges for the module from a client perspective. The challenges were broad in scope and covered complex socio-economic problem areas such as healthy ageing and net zero. Digital transformation projects benefit from structured project management taxonomies that guide planning and execution in complex environments (Tarannum, 2025). It was also recognised that while Agile originated in software development it is now widely adopted in other sectors like healthcare, finance, and marketing. This was reflected in the assessment challenges, which were broad in scope. Working in Agile teams, students needed to use Agile tools and techniques to devise a solution to the challenge. The solution deliverable did not necessarily need to be a piece of software. Students initially used the Pugh matrix to help with making a decision about which project to choose and which particular problem area to focus their solution on. The assessment was designed so that students could build up their assessment as the module progressed. Materials were made available in advance for those students that wanted to forge ahead with progress.

Students had the opportunity to choose their own group of 4 or 5 students to work with on the assessment challenge. Students were encouraged to adopt an Agile mindset and culture to their groupwork, which included fostering open discussion/communication, active collaboration, embracing change, regular reflection, and iteration, and the importance of interacting with the industry experts as the client. Tutors gave students regular feedback on a weekly basis on their progress during class together with being available to answer any questions for clarification on the assessment requirements. In particular, tutors asked students about the progress that they had made during the previous week and what they had planned for the following week. Progress was noted down by the tutor so that they could be referred to in conversations with students the following week and also to show the student that the tutor was taking an active interest in their progress. Taking comments from mid-module feedback into consideration also helped with refining the teaching process further.

The assessment required students to work iteratively and collaboratively. The assessment aimed for hands-on work to analyse system and user requirements, create and update plans as well as iteratively model and present plans for implementation. To achieve the aim, students worked in teams to deliver a number of iterations of a prototype (practicing sprints and scrums). They presented the proposed solution as a team presentation and answered questions on its development.

In order to successfully complete the assessments students needed to engage with stakeholders to identify requirements, propose a solution, and communicate plans for implementation using Agile project management and information systems tools, and techniques. Students worked in teams to practice Agile development, working iteratively to prioritise, delegate, and deliver tasks while responding to changing requirements. The marking criteria encouraged the usage of different Agile tools and techniques, effective collaborative group work, planning, and creative and innovative solutions to the challenge.

Suggestions of Agile tools and techniques were made for each of the aspects of the marking criteria. For example questions within the marking criteria helped students to focus on particular aspects of the project: Is there clear evidence of background research on the wider challenge and specific problem shown? Is the problem clearly framed from a user perspective, with requirements that are understandable and relatable? Is the problem clearly framed from a systems perspective, with data/information flow clearly and correctly demonstrated? The following deliverables were suggested to fulfil such criteria: screenshots of background research; user personas, user stories, functional requirements, non-functional requirements, system flow chart.

Students also completed an individual element to the assessment. This involved creating a log book of evidence of tools and techniques used throughout the project. This was shown in screenshots, images, etc. rather than lots of text. Students were encouraged to provide evidence for each element of the marking criteria. For example: Have you shown detailed project plans? Have appropriate planning tools and practices been applied appropriately? Evidence for this was suggested as (but not limited to) a Work Breakdown Structure and Gantt chart.

The industry experts were also invited to give a guest lecture to show students the sorts of Agile projects that had transformed their business, together with key lessons learned and future plans for adopting Agile in their business. It also helped students to understand how Agile principles are applied in actual work environments. The industry experts also came into a seminar to listen to the ideas that students had for solutions to the assessment challenges. They were then able to give them feedback from a practice/industry point of view on ways to improve it for subsequent iterations of the prototype. The feedback received from students was really positive and the excitement built in-class knowing that they would get to talk directly to the industry experts who had set the challenges. The guest lecture acted as a way of inspiring students' ambitions to work in Agile teams and apply for Agile project management roles. This reflects wider evidence that mentoring plays a critical role through project management processes directly influencing skilled development and performance (Tan & Leong, 2025).

After students had submitted their assessments and these had been marked by tutors, the industry experts gave the students that submitted the best projects a prize which was a recommendation on LinkedIn. This acted as a mechanism for encouraging excellent project performance and as a way of showing future potential employers the areas that students had excelled in. There was also an opportunity for the most innovative and creative ideas to be taken forward by the industry experts as practically realized solutions. Again, strengthening the academic and industry bonds and enhancing student engagement towards a real-world realized outcome.

Establishing good communication channels with industry experts also helped with continuously updating and refining the Agile curriculum based on the evolving needs of the industry. This ensured that the teaching remained relevant and that students were equipped with the most up-to-date practices and tools. Students were also provided with guidance on how Agile can lead to specific roles like Scrum Master, Product Owner, Agile Coach, or Project Manager, and what steps are needed to achieve these positions. By showing students job adverts with salaries and skills needed helped to encourage enthusiasm for Agile ways of working and learning in preparation for the graduate employment market. Such involvement helped to accelerate learning and career readiness.

4.2. Experience – work placement module

All undergraduate students were required to find a graduate role/s for their work placement year. Students are required to work at least 16 hours per week over a minimum of 30 weeks. If more than one placement is undertaken each placement must last at least 5 weeks. Although the responsibility of securing a placement rests with the student, the university provides lots of support to help students to find a suitable placement.

The aim of the work placement assessment is to demonstrate the effective amalgamation of skills developed in the professional environment and academic learning. Through the exploration of the chosen issue or process for the organisation or its business environment, the student will demonstrate their ability to identify matters of importance to the organisation, explore them, and put forward practical solutions for improvement. This element of the assessment requires that students employ their interpersonal, analytical, problem-solving, and communication (verbal and written) skills throughout. It should be noted that interpersonal and other communication skills are important when undertaking the investigation as well as PM skills and techniques. These are all sophisticated employability skills which should be evident from the finished assessment and its delivery. The choice of topic may relate directly to the area in which the student works, to a wider part of the organisation, or to the business environment in which it operates.

On successful completion of the Placement year and Undergraduate Placement Assessment, a student will have, as a minimum, demonstrated their capacity to engage effectively with the terms of their placement contract(s). In addition, students who exceed the above minimum pass threshold will be able to demonstrate increasing personal and professional development; articulate key personal, cultural, professional, and disciplinary knowledge, and skills relevant to the placement experience and reflect on performance; and clearly communicate the ways in which placement-related skills can be transferred to support ongoing personal, professional, and academic development.

Students will need to complete an individual portfolio comprised of the following components: six work-based reflective pieces of work which reflect defined areas of work-based developments. This is then supplemented by a critical evaluation of an issue or process within your organization(s) or relevant business sector including recommendations and actions as appropriate, through a recorded video. This application of skills such as project management and stakeholder management help students to experience PM on a hands-on basis. They can apply Agile skills and PM to a real-world context.

Each student is allocated a work placement supervisor from the University. The University supervisor guides the student through the assessment process and gives feedback through regular meetings. This helps students to refine their ideas and develop each assessment aspect. Work placement supervisors also advise on the topic area to focus on for the presentation aspect of the assessment. Prior to starting the presentation project part of the assessment students complete a project outline and ethical form to ensure data collection has been considered from an ethical point of view and that the topic area studied relates to relevant literature and business theories. Students are encouraged to take an Agile approach to their management of each part of the assessment and reflect this in their end deliverable.

4.3. Application – SSM consultancy module

Many graduates moving from a business school education to employment encounter a growing amount of uncertainty and complexity in business and industry. The amount that can be taught solely through cognitive processes is limited, and students can also learn best through doing and engaging with others. Students must learn how to solve problems in real-world scenarios. This module's assessment goal is to provide a team-based activity that tackles the pedagogical conundrum of how to foster and evaluate the development of such abilities. Skills such as leadership, team working, problem solving, and conflict management can be developed in this scenario. The use of problem-based learning to increase students' competency and confidence in handling difficult and unclear problem situations sometimes known as "wicked problems" is what makes this scenario and activity innovative.

This exercise is used with final-year (level 6) undergraduate students at Aston University. The activity runs throughout one ten-week term. Eight weeks are based on the planning of the event. Then, two weeks are the event window in which students choose a 24-hour window to run their event.

Students are organized into teams of five or six and challenged to raise as much money as possible for their chosen charity/charities in a 24-hour window. The teams compete against each other, particularly in relation to the amount raised.

The team context of the activity is important since students learn not only about their own performance in problem solving but also about the interpersonal and group dynamics of team working. The creativity of the fund-raising idea and how well the team worked together are also assessed. A peer review assessment of each other's contributions is assessed through online software called Teammates. Finally, each student will submit a reflection of their journey on the module, based around a reflective cycle and three critical incidents that would have happened during the fundraising event, from planning, execution, to post execution.

The planning for this fundraising event uses the Soft Systems Methodology (SSM) (Checkland, 1986). SSM has been successfully used in many different contexts for complex problem-solving (e.g., Aryee & Hansen, 2022; Sharma, et al., 2019). This is an approach that uses stakeholders and relationships and interactions to understand the complex and ambiguous challenge that the students are facing when first planning for the fundraising event. With its seven-stage structure it provides a framework for structuring and framing wicked problems by initially thinking about what is happening in the real world from the point of view of different stakeholders. The comparison between the real world and idealized worlds allows for an eventual accommodation of future ways forward. The use of rich pictures and modelling of activities help to plan for the event and understand the dynamics of the different stakeholders. Understanding the world views of the stakeholders are important to understand how to manage these interactions.

As the future leaders of a society that is increasingly complex and challenging it is important that higher education students have a good grasp of social, political, economic, and environmental issues and also feel equipped to propose reasonable recommendations. The use of the SSM in a scaffolded, group-based learning approach provides students with a framework to learn about and engage with complex issues.

The module aims to understand different approaches to structure a consulting intervention. Students will develop an understanding of effective versus ineffective consulting practices through experience and critical reflection. Students will be better prepared to carry out successful consulting projects within organizations, either as an external investigator or as a line manager given a one-off problem-solving task. Students successfully completing this module will be able to design and execute a fundraising event in a complex and ambiguous situation, evaluate, and select appropriate consulting methods and tools for their challenge, reflect on their consulting practice, and performance both as an individual and in the context of a team activity.

SSM is used to plan and structure the event. Stakeholder management and PM is central to this planning. Students work in teams 5 or 6 and use SSM analysis to explore the design and execution of the event. Students are encouraged to use empathetic discourse to experience what the stakeholder wants and needs in the context of the fundraising event. Empathy enriches the SSM process by ensuring the human side of systems is as important as the technical side (Bentley, 1993). It is about creating solutions that work not just in theory but in real, messy, human-centric environments (Checkland & Scholes, 1999). Understanding worldviews in relation to project management learning and teaching is important as it shapes how individuals and organizations approach problems, decision-making, and strategies. A worldview is a broad perspective or belief system that influences how people perceive and interact with the world (Checkland & Poulter, 2006). Being aware of worldviews in operations management allows organizations to operate in a more inclusive, thoughtful, and adaptive manner, ultimately leading to more effective practices and learning outcomes.

The module is assessed by group work and individual assessment. Group work is assessed through fundraising event design and creativity, the amount raised for charity, and then peer assessments of team members. Stakeholder management and conceptual project management principles are applied during the fundraising activity. Students then write a portfolio that should be a reflective account of their overall experience of the challenge, from the initial launch of the activity to the post activity reflection and analysis. The purpose of the portfolio is for the student to demonstrate an understanding of the application of the ideas and concepts of the module in the delivery of a real-world consulting assignment. The reflective nature of the account gives the student the opportunity to critically analyse their experience, both as individuals and as team members. Students are asked to reflect on their experiences and be self-aware and also aware of team members feelings and emotions. The critical aspect of the reflection is important since it involves assessing the strengths and limitations of the various concepts and theories when applied in the real world.

5. Student evaluation of the scaffolded approach to assessment

Overall, there were clear improvements to students grasp of Agile concepts throughout the three years of study. At the end of each module students were asked to evaluate the overall learning experience. The sections that follow show interesting students quotes which help to give a flavour of their experiences and opinions.

5.1. Agile module

For the Agile module students made a number of positive comments about the learning, teaching and assessment. In particular they liked the clear explanations and content provided to support the development of a prototype solution together with working in a group and building skills throughout the module. These are some examples of quotes from students.

> *"I really enjoyed the module. It was well-structured and helped me to understand Agile practices more effectively, which I found extremely beneficial".*
>
> *"The lecturers clear explanations and guidance significantly enhanced my understanding of Agile concepts. The feedback provided was always informative and effective, enabling me to improve my work to a great extent".*
>
> *"I really enjoyed working as a group on a challenge and identifying problems and proposing user-centric solutions".*
>
> *"Knowledge is buildable with lots of skills demonstrated that are useful in multiple areas".*
>
> *"The content is interesting, and loads of information have been provided to help us deliver our project. I'm quite pleased, with the way we have been given the freedom to choose our group members and also the way independency is being encouraged to go about the project".*
>
> *"The planning and process of how to achieve what we need is very helpful".*
>
> *"We have a lot of time to interact with our group members to develop the assignment during classes".*

The industry experts involved in the module commented on their experiences of working with the students. In particular they positively commented on giving feedback to students, contributing to their learning experience and real-world nature of the challenge set. These are some examples of quotes from the industry experts.

> "*It's great to hear that the session was useful and sparked enthusiastic discussions among the students. We are glad to contribute to their learning experience and hope the session provided them with more confidence as they progress with their projects".*
>
> *"We enjoyed working with the students and were impressed with their ability to turnaround substantial work within the short period. The students' creative approach to the challenges brought fresh ideas and demonstrated essential skills beyond basic brainstorming. We are well pleased to see the students pushing the boundaries with the careful guidance of their lecturers".*
>
> "*From our end, we believe these goals were achieved: helped students with real-life or real-time business problems to provide the experience of a real-world scenario; provided a big picture point of view on how to solve/address global problems such as Healthy Ageing and Sustainable Development goals from a holistic angle and include*

these in their solutioning; and motivated them by giving constructive feedback through our experience and sharing with them some of the tools and methods that we deploy in our consulting practice".

5.2. Effective management consultancy module

The Effective Management Consultancy module also received a number of positive feedback comments from students. Some examples are given below. In particular students liked the helpful and supportive nature of the module, the creativity aspect and practical seminars.

"The flexibility in the module is nice as it doesn't feel like a traditional academic module".

"The module is really good and will be very useful in the future. Probably one of the most interesting modules so far in the degree. Lecturers are really good, supportive and helpful".

"An exciting module that differentiated itself from other typical modules. I am enjoying the creativity aspect of the module as we are free to create whatever event we want. The seminar times are well structured giving us enough time to work through content but also have enough time to conduct group work".

"Interesting concept, different to other modules".

"The seminar is very practical and engaging. All information is delivered clearly, and help is available immediately when unsure of something".

"Unique course, allows students to be creative".

6. Discussion

6.1. Theoretical implications

This study contributes to the growing body of literature on Agile pedagogy and scaffolded learning by demonstrating how a structured, multi-year assessment framework can enhance student engagement, deepen learning, and improve employability outcomes. Drawing on Bruner's (1966) theory of scaffolding and Vygotsky's (1978) Zone of Proximal Development, the framework operationalises these concepts through a sequence of assessments that build progressively from understanding to experience and application. The findings support Murtagh and Webster's (2010) assertion that scaffolded teaching and assessment can lead to improved academic achievement when aligned with student needs and learning outcomes.

Moreover, the integration of Agile project management into non-software contexts such as consultancy, fundraising, and placement-based challenges extends the theoretical understanding of Agile as a flexible, cross-disciplinary methodology. This aligns with recent research (Noleto et al., 2023) that highlights Agile's adaptability across sectors and supports the argument that Agile is not confined to software development but is a broader project management philosophy.

The study also reinforces the importance of authentic, real-world learning experiences in higher education. By embedding industry collaboration and iterative feedback into the curriculum, the framework aligns with constructivist theories of learning and supports Freire's (1984) call for education that is relevant to students' lived experiences.

6.2. Practical implications

From a practical standpoint, the scaffolded assessment framework offers a replicable model for other higher education institutions seeking to enhance student engagement and employability. The use of real-world challenges, industry-set assessments, and iterative feedback mechanisms mirrors Agile principles and prepares students for the dynamic demands of the modern workplace. The positive student feedback and improved attainment outcomes suggest that this approach not only enhances academic performance but also fosters critical soft skills such as teamwork, communication, and adaptability.

The study also highlights the importance of consistency and clarity in scaffolded support. As noted by Stanier (2015), mismatches between tutor and student expectations can undermine the effectiveness of scaffolding. Therefore, institutions adopting this model should ensure alignment across modules and academic years, with clear communication of assessment criteria and expectations.

Furthermore, the integration of Agile tools and techniques into the curriculum such as Jira, Trello, and Planning Poker provides students with hands-on experience that is directly transferable to industry settings. This practical exposure, combined with reflective assessments and peer feedback, equips students with a holistic understanding of Agile project management and its real-world applications.

7. Conclusion

Agile methodologies are increasingly recognized as essential for graduates entering dynamic work environments (Greenburg et al., 2022). Teaching Agile to undergraduate students can help to build knowledge of Agile technicalities together with soft skills, increasing their attractiveness to employers. Teaching Agile effectively can equip students to adopt a dynamic, collaborative, and customer-focused way of working. In particular linking industry with teaching Agile creates a mutually beneficial relationship between students, academics, and employers. For industry, organisations can gain access to bright talented students, sparking new idea creation potentially helping them to remain competitive in their respective markets. For students it ensures that they gain relevant, practical skills making them more employable in various sectors. It prepares them for effectively contributing to high-performing teams and provides opportunities to work on real-world projects that simulate industry challenges.

Continuous feedback, learning from failures and incremental improvement were key parts of the modules in the case study discussed in this paper that assisted in fostering Agile ways of working amongst students. Through the modules students gained hands-on experience in managing sprints and collaborating in a team to produce an end-product, all of which contributed to increasing their overall engagement in the subject area. Such practical experiences are strong selling points in job interviews. Through industry links academics were able to ensure that teaching materials were in line with current industry techniques and standards, students were actively engaged, and the assessments were relevant to real-world situations. By considering understanding, experiencing and application in a scaffolded assessment framework students were able to be actively engaged in their learning experience and gain hand-on transferable workplace skills. Studying alongside their peers in group-based project work helped to further embed and enhance knowledge and skills into their repertoire. The use of scaffolding in particular helped to structure assessments providing tutor, peer, and industry support during the learning journey.

This is ongoing research as future refinements to the teaching and learning techniques will be made and additional ways for linking industry and academia in the modules will be explored. Other future research could include the exploration of the use of AI to see how industry is now using this and the effect it is having on Agile teams in the workplace. The same teaching techniques employed at Aston could be replicated at other universities with a different cohort of students and results compared to ascertain challenges and opportunities. Learners could be prepared for larger scale projects and leadership roles in large organisations by the closer collaboration of different teams.

While the findings of this study are promising, several limitations should be acknowledged. First, the research is based on a single case study at one UK-based university, which may limit the generalisability of the results to other institutional contexts or international settings. Second, the evaluation of student outcomes was primarily qualitative, relying on student feedback and tutor observations, rather than longitudinal or quantitative measures of academic performance or employability. Third, the study did not include a control group or comparative analysis with non-scaffolded assessment approaches, which would have strengthened the causal claims regarding the effectiveness of the framework. Finally, while industry involvement was a key strength, the variability in industry partner engagement across cohorts may have influenced the consistency of student experiences.

Having Agile knowledge and experience can help to set job candidates apart from those without these skills. In competitive industries like technology, Agile experience on a curriculum vitae can signal to employers that a candidate is ready to contribute to Agile teams and projects from the start of their employment. As Agile continues to evolve and influence project management, having Agile expertise ensures that candidates stay relevant and competitive in the future job market.

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