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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.

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Special issues focused on important specific topics will be evaluated for publication.

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EDITORIAL

It is our great pleasure to bring you the fourth number of the 13th volume of IJISPM. In this issue, readers will find important contributions on ethical considerations in artificial intelligence projects, risks and disruption mitigation, benefits realisation management, and project management education.

Ethical considerations in the AI lifecycle for design, developing and adopting AI in public sector – the case of Finland

Ari Alamäki, Umair Ali Khan, Altti Lagstedt

This study explores the role of ethics in all phases of AI projects. Through qualitative interviews with the public sector actors in Finland, the study identifies key ethical concerns related to the lifecycle of AI. The findings highlight the need for embedding ethical requirements throughout the AI system lifecycle and emphasize the role of human-centered AI systems. By utilizing empirical data from multiple public sector case organizations, this study provided both theoretical insights and practical guidelines for developing ethically aligned AI systems. The findings emphasize the need for a comprehensive, lifecycle-oriented approach to ethical AI design, development, adoption, and use. The AI lifecycle spans various phases that collectively shape the ethical impact of AI applications. This research provides empirical insights into how ethical considerations can be practically integrated from the design to adoption phases of AI. By embedding ethical practices throughout the lifecycle, organizations can anticipate and mitigate risks more effectively.

Contribution of big data analytics to risks and disruptions mitigation and agility performance

Aziz Barhmi, Soulaimane Laghzaoui

The main objective of this study is to understand the mechanisms by which supply chain data analytics (SCDA) capabilities impact supply chain agility performance (SCAP) directly or through the mediation of other capabilities, particularly supply chain risk mitigation (SCRMI), supply chain robustness (SCROB), and supply chain resilience (SCRES). The study is based on survey data collected from 203 foreign companies in global value chains located in Morocco's industrial acceleration zones, whose legal status is assimilated to foreign territory. Respondents were mainly senior and middle managers with experience in general management and operations and supply chain management. Validity and reliability analyses as well as hypothesis testing were performed through structural equation modeling (SEM) using SPSS Amos. The results showed that SCDA capabilities strengthen the capabilities of SCRMI, SCROB, and SCRES and indirectly improve SCAP through partial and exclusive mediation of SCRES capability. The results of this study revealed the importance of developing SCDA capabilities for strengthening risks and disruptions mitigation capabilities and improving SCAP. Also, optimizing the return on investment in SCDA capabilities should incorporate dedicated risks and disruptions mitigation tools and alerts to facilitate supply chain managers' decision making in this area.

Exploring temporal dimensions of benefits realisation management in agile IT environments

Julie Delisle, Carl Marnewick, Alejandro Romero-Torres

This study explored the temporal dimensions of benefits realisation management (BRM) in agile IT project management environments. BRM, focused on aligning strategy with project execution, is inherently temporal, requiring the consideration of past, present, and future outcomes, as well as both short- and long-term benefits. This research explored BRM in agile IT project management through a temporal lens. Adopting a 'time as process' lens, our interest was in how actors collectively negotiate, enact, and interconnect the present, past, and future. Through qualitative interviews and a focus group, we examined how agile methods, specifically Scrum and SAFe, interact with BRM processes across different time perspectives. The findings identify challenges such as (1) limited availability of past project data, (2) neglect of long-term benefits, and (3) lack of harmonisation between past, present, and future considerations in benefits realisation. The paper contributes to project management literature by emphasising the importance of temporal leadership in navigating these challenges and improving the harmonisation of past, present, and future actions in BRM.

Unveiling the potential of metaverse in project management education

Tufan Özsoy

The Fourth Industrial Revolution (4IR), driven by technological advancements such as Artificial Intelligence (AI), has transformed industries, reshaping the skills required in the workforce. Project management education must adapt to these changes by integrating innovative teaching methods to prepare future professionals. This study explores the potential of the metaverse, an immersive virtual environment, to revolutionize project management education. By offering interactive, real-time simulations and personalized learning experiences, the metaverse enables learners to engage with complex project management scenarios beyond the limitations of traditional classrooms. This research combines a literature review and qualitative analysis of project managers' perspectives to assess the benefits and challenges of incorporating the metaverse into educational curricula. The findings highlight the potential for enhanced engagement and the barriers to adoption, including technology access and learning curve concerns. The study concludes by proposing future research directions and addressing limitations regarding the scalability and effectiveness of metaverse-driven education in diverse project management contexts.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like 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 the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Editor-in-Chief,

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RESEARCH ARTICLE

Ethical considerations in the AI lifecycle for design, developing and adopting AI in public sector – the case of Finland

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Abstract
This study explores the role of ethics in all phases of AI projects. Through qualitative interviews with the public sector actors in Finland, the study identifies key ethical concerns related to the lifecycle of AI. The findings highlight the need for embedding ethical requirements throughout the AI system lifecycle and emphasize the role of human-centered AI systems. By utilizing empirical data from multiple public sector case organizations, this study provided both theoretical insights and practical guidelines for developing ethically aligned AI systems. The findings emphasize the need for a comprehensive, lifecycle-oriented approach to ethical AI design, development, adoption, and use. The AI lifecycle spans various phases that collectively shape the ethical impact of AI applications. This research provides empirical insights into how ethical considerations can be practically integrated from the design to adoption phases of AI. By embedding ethical practices throughout the lifecycle, organizations can anticipate and mitigate risks more effectively.

Keywords
artificial intelligence; software development; ethics of AI; AI lifecycle; project management.

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1. Introduction

The public sector is in the early stages of adopting artificial intelligence (AI) (Selten & Klievink, 2024; Straub et al., 2023), although it will be an important technology for public management processes (Misra et al., 2023; Neumann et al., 2024). AI remarkably enhances the data collection and analysis possibilities, enabling automatic learning, decision making, and prediction. AI is an essential part of the Industry 4.0 revolution and the change of work (Frey et al., 2016; Jan et al., 2023; Leesakul et al., 2022) which also applies to public sector actors. Since AI will have a significant impact on the development of work and organizations, the related ethical discussion is of paramount importance (Ashok et al., 2022a; Huang et al., 2023). It is typical for AI solutions that they are updated with new teaching data even during use. Consequently, their operation and applicability may change over time. In addition, the ethical questions related to decommissioning the AI solution should also be considered. Therefore, ethical considerations should not be seen as just one step in the planning phase of AI solutions, but the entire lifecycle of an AI solution, including operations, maintenance, and retirement, should be taken into account (Huang et al., 2023).

The use of AI in organizations can be roughly divided into two different use case categories: i) the organization's own data is used, and their own AI solution is built, or ii) pre-trained generative AI is used. Especially the rapidly evolving field of generative AI is bringing forth new ethical and trustworthiness challenges. Generative AI holds significant potential to revolutionize the public sector, yet it simultaneously poses distinctive challenges. Especially, the increasing integration of large language models (LLMs) into critical areas such as education, healthcare, and business necessitates the development of robust methods to verify the authenticity, ownership, accuracy, and ethical use of the content they generate. Moreover, issues such as the lack of explainability, transparency, and accountability are becoming increasingly prominent in generative AI solutions. Recent evaluations (Bommasani et al., 2023) indicate that major LLMs, including both proprietary and open source, do not adequately meet the requirements of the EU AI Act (European Parliament, 2023). Although the providers of these LLMs excel in enhancing efficiency through the integration of extensive training data and adding multimodal capabilities, the growing focus on transparency and the categorization of AI applications' risks, as outlined by the EU AI Act, is crucial. This emphasis is essential for ensuring safety and upholding the fundamental rights of individuals and businesses (European Commission, 2024). Thus, it is crucial to understand the ethical implications of the integration of AI applications built on the LLMs into the public sector. Additionally, public organizations face many other challenges regarding AI, such as perceived financial costs, organizational innovativeness, governmental pressure, government incentives, data privacy concerns, lack of skilled personnel, and resistance to change (Misra et al., 2023; Neumann et al., 2024; Sun & Medaglia, 2019). Thus, more research is still needed in this field (Andrews, 2019).

The ethical discussion is often overshadowed by the technological and economic exploitation of AI's potential. Therefore, it is crucial to emphasize ethical questions more prominently in the discourse. There has already been some discussion about taking ethics into account during the AI life cycle (see e.g. Huang et al., 2023). Therefore, there has been relatively little thought about, for example, the use of AI in the public sector. There is clearly a need for more versatile studies on the matter. To address this, we formulate the following research questions:

1. What ethical issues are emphasized as a part of AI system design, development, and adoption in case organizations?
2. How should ethical consideration be integrated into AI system life cycle phases in the public sector's organizations?

To answer these research questions, we first analyzed the existing ethical frameworks at different stages of the AI lifecycle. Subsequently, we analyzed the ethical AI issues and AI frameworks at the AI system lifecycle level. In addition, we also analyzed this issue from the lens of information system (IS) development and suggested the main goals that should be considered in the AI development process. We found that most relevant studies assessing ethical considerations in the AI system lifecycle are conceptual and lack empirical evidence. Our case study, including interviews with the AI adopters and potential AI adopters in the public sector and the subsequent qualitative analysis of the interview data, highlighted the practical ethical challenges and concerns.

The rest of the paper is structured as follows. Section 2 presents the related work, providing an overview of existing ethical frameworks and studies on AI development, especially in the public sector. Section 3 outlines the research methods, detailing the qualitative case study approach, participant selection, data collection, and analysis techniques. Section 4 presents the findings from the interviews, categorized into key AI application areas, ethical challenges, and design considerations in public sector AI adoption. Section 5 offers a discussion of the results, connecting them with the existing literature and ethical AI frameworks. Section 6 highlights the limitations of the study and outlines a future research agenda for exploring ethical AI development further. Section 7 concludes the paper.

2. Background

Ethical considerations are increasingly crucial in the development and deployment of AI systems within their rapidly changing landscape. While AI presents substantial socio-economic advantages, it is important to acknowledge that the same mechanisms driving these benefits may also pose significant risks. For example, AI has the potential to cause both tangible harms, such as jeopardizing individual safety and health, including potential loss of life and property damage, and intangible harms, including breaches of privacy, constraints on freedom of expression, threats to human dignity, and discrimination (Nikolinakos, 2023). As AI applications continue to expand, establishing guidelines for ethical and responsible behavior in AI system development is becoming critically important. In recent years, several AI frameworks have been proposed, such as the EU's ethical guidelines for trustworthy AI (High-Level Expert Group on AI (AIHLEG), 2018) focusing on ensuring that AI systems are transparent, fair, and uphold privacy and dignity. AI Act (European Parliament, 2023) categorizes AI systems by risk and sets compliance standards for high-risk applications. OECD AI Principles (Floridi & Cowls, 2019) focus on human-centric values, transparency, and accountability across sectors, among others.

Although these frameworks serve as reference guides for developing responsible AI systems, they are typically high-level and do not provide concrete guidance on how to develop such systems (Lu et al., 2022, 2023; Sanderson et al., 2022). It remains largely unclear how these principles and values be converted into requirements for responsible AI systems, and what developers and the organizations developing these systems should do (Vakkuri et al., 2021). Due to this limitation, the developers often lack explicit knowledge on how to apply these guidelines during the system development process (Ronanki, 2023).

To tackle this issue, some studies adopted an empirical approach involving interviews with scientists, engineers, and developers to understand the practitioners' views on AI ethics principles and their implementation. Prior research (Kamila & Jasrotia, 2023; Lu et al., 2022; Sanderson et al., 2022) find privacy and security, bias and fairness, trust and reliability, transparency, and human-AI interactions as major ethical concerns. Lu et al. (2022) find that ethical risk assessments in AI are often one-time actions, ethical requirements are vaguely defined, system-level design considerations are overlooked, and there is insufficient support for continuous ethical monitoring post-deployment. Sanderson et al. (2022) adopted a software engineering approach covering four aspects: i) high-level view highlighting the do-once-and-forget approach in practice, maintaining trust from data providers, attaching ethics credentials to AI components and products, significance of system-level approach to AI development, ii) ethics requirements highlighting privacy and security as the prerequisites, normative, descriptive, and temporal aspects of responsibility, iii) design and implementation emphasizing overriding AI decisions by human's, reliability vs. fairness tradeoff, preferred use of trained AI models and related components, and explainability of decisions, and iv) deployment and operation highlighting monitoring and validation to ensure the adherence of AI systems post-development, and tracking the use of AI systems.

Some studies employed desktop research to review the existing academic literature on ethical concerns, requirements, limitations, and risks in AI system development (Huriye, 2023; Kamila & Jasrotia, 2023). Huriye (2023) identified bias, privacy, accountability, and transparency as key ethical issues, emphasizing the need for stakeholder collaboration and a human-centered approach that values local community needs. Kamila and Jasrotia (2023) also highlighted similar concerns, including privacy and security, bias and fairness, trust and reliability, transparency, and human-AI interaction. Ashok et al. (2022b) identified 14 ethical implications across seven technology archetypes and emphasized key principles such as accountability, fairness, and privacy. Similarly, Huang et al. (2023) addressed ethical risks such as privacy leakage, discrimination, and security concerns arising from AI applications.

Prior studies addressed this issue by proposing comprehensive methods to develop ethical AI systems. For instance, Vakkuri et al. (2021) proposed a sprint-by-sprint process that takes on the form of a deck of 21 cards, covering 8 AI ethics themes, which also covered the AIHLEG's Ethics Guidelines (High-Level Expert Group on AI (AIHLEG), 2018) including (1) human agency and oversight; (2) technical robustness and safety; (3) privacy and data governance; (4) transparency; (5) diversity, non-discrimination and fairness; (6) environmental and societal well-being; and (7) accountability. Using this framework, one can select the cards that are relevant to their work and then evaluate the situation again after each sprint. This approach results in a paper trail of choices and trade-offs that document the ethical considerations conducted during development. However, this method does not suggest how the cards should be selected for a specific development phase.

2.1. Ethical Issues at the AI System Lifecycle Level

Several studies emphasize the application of ethical principles to the entire life cycle of AI systems (Lo Piano, 2020; Taddeo et al., 2024). The OECD Framework for the Classification of AI Systems (OECD, 2022) also highlights the need for ethical considerations throughout the entire life cycle of AI systems. Similarly, the NIST AI Risk Management Framework (AI NIST, 2023), which closely follows the OECD's definition of the AI lifecycle, also emphasizes the importance of ethical considerations at each development stage.

The AI system lifecycle encompasses several stages that guide a project from concept to operation and monitoring. Ethical considerations must be addressed from the early phases (Lahiri & Saltz, 2024), as several critical decisions are required, such as data collection, risk evaluation, infrastructure selection (including hardware, software, and platforms like Microsoft Azure), and AI model selection. Understanding the type of information management department, we are dealing with is crucial. Additionally, we need to assess how agile the organization is and how straightforward it is to make these decisions.

The granularity of the AI lifecycle varies from study to study. From an ethical perspective, the AI system lifecycle is more complex than the traditional system lifecycle. An insufficiently differentiated lifecycle can lead to blind spots and the creation of ethical risks. Conversely, identifying too many stages (with related tasks) can make the iterative application of ethical principles cumbersome, rendering the ethical guidelines unwieldy (Taddeo et al., 2024).

Different studies outline varying phases of the AI system lifecycle. Some studies, such as the OECD digital economy papers (OECD, 2019) and the NIST AI Risk Management Framework (AI NIST, 2023), define six phases: plan and design, collect and process data, build and use model, verify and validate, deploy and use, and operate and monitor. Similarly, other studies describe three (De Silva & Alahakoon, 2022), four (Amugongo et al., 2023; Floridi et al., 2022), and five (Huang et al., 2023) phases of the AI system lifecycle. Based on various studies, we identify five basic stages in the AI system lifecycle: design, develop, deploy, operate, and retire which encompass all the actions across all phases defined by the existing studies.

Each phase includes three dimensions: actions, actors, and ethical/risk considerations. Additionally, each phase encompasses specific AI principles that define the ethical aspects within that phase as overarching principles (OECD, 2019). Therefore, the AI system lifecycle can be viewed as a five-dimensional model.

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Figure 1 illustrates the AI system lifecycle and its five dimensions. Each phase involves specific actions that represent the activities within that phase. Based on these activities, each phase requires certain expertise or roles, making the AI system lifecycle a multidisciplinary approach that demands more competence than the traditional system lifecycle.

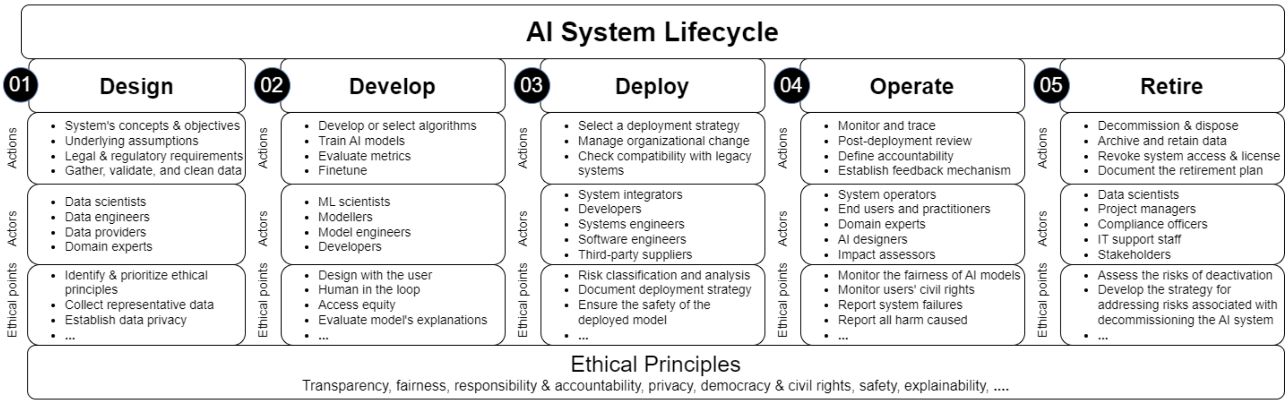

Fig. 1: Synthesis of existing studies: AI system lifecycle showing the dimensions of stages, actors, and the ethical/risk considerations

The design phase, in particular, involves a broader range of expertise, which signifies its importance. The data scientist responsible for the design phase typically holds a senior position with several years of experience. They must be able to formulate the problem and conceptualize a solution by drawing on existing literature and their past experiences with diverse AI projects. Additionally, they should be adept at identifying representative, required, and available data by collaborating with other phases of the lifecycle (De Silva & Alahakoon, 2022). Since the design phase sets the foundation for the entire AI project, ethical considerations at this stage are most important, as they have long-lasting impacts (Brey & Dainow, 2024).

Certain ethical principles govern ethical behavior within each phase of the AI system lifecycle. These principles, derived or inspired by those set by (High-Level Expert Group on AI (AIHLEG, 2019), are applied differently across various studies. For example, the OECD digital economy papers (OECD, 2019) outline five ethical principles: i) benefiting people and the planet, ii) human-centered values and fairness, iii) transparency and explainability, iv) robustness, security, and safety, and v) accountability. This study also explains how each AI principle can be assessed at specific phases of the AI lifecycle. Hence, for each phase, there exists a set of ethical considerations that correspond to specific AI principles.

Huang et al. (2023) assess ethical considerations in a five-phase AI system lifecycle using ethical principles such as transparency, fairness, responsibility and accountability, democracy and civil rights, sustainability, privacy, and safety. Similarly, Amugongo et al. (2023) focus on fairness, transparency, ethics by design, trust, precision, and safeguarding humanity in a four-phase lifecycle. Floridi et al. (2022) propose a five-phase model with principles like societal welfare, accountability, governance framework, responsibility, performance, environmental impact, fairness, accuracy, traceability, privacy, explainability, and robustness, providing guidelines for each phase. Taddeo et al. (2024) adopt Floridi's model, emphasizing transparency, responsibility, traceability, robustness, privacy, and accountability.

It is worth mentioning that privacy in the AI lifecycle is a two-fold approach that encompasses "Privacy by Design" and "Privacy by Default" to ensure both regulatory compliance and the protection of individual rights (Navaie, 2024). "Privacy by Design" involves integrating privacy measures into the design and architecture of information systems from the outset, rather than as an afterthought. This proactive approach ensures that privacy is an integral component of the system's functionality. "Privacy by Default" complements this by ensuring that personal data is automatically protected in any given system or business practice, meaning that the default settings are configured to the most privacy-friendly options. These concepts are emphasized in regulations such as the General Data Protection Regulation (GDPR), which mandates that data protection measures be implemented by design and by default. By incorporating these principles, organizations can ensure that personal data is handled with the highest standards of privacy protection throughout its lifecycle.

In summary, various studies have employed different levels of granularity in AI system lifecycle models and applied diverse sets of ethical principles across lifecycle phases. Although the number of ethical principles used in each study varies, they generally align with those established by (High-Level Expert Group on AI (AIHLEG), 2019) and its older version.

In our study, we primarily address ethical considerations in the AI lifecycle from a conceptual standpoint, by providing a grounded, empirical perspective. The case study in this paper captures and validates the views of various stakeholders directly involved in different stages of the AI lifecycle. This approach bridges the gap between theoretical ethical frameworks and practical, real-world challenges, aligning the insights from practitioners with ethical guidelines previously established in literature.

2.2. AI Ethics in Information System Development

The first three phases of the AI life cycle (Figure 1) are easily overlooked as they are not so visible to the end users (De Silva & Alahakoon, 2022). The developers (typically from an external company) have a key role in these phases. Commonly, development is outsourced, and it is tempting to think that the responsibility has been transferred to "someone else" (Hedlund & Persson, 2025). However, these three phases play a very significant role in the implementation of an ethically sustainable AI solution, and therefore, we will go through the first half of the AI life cycle in a little more detail next.

Typically, an information systems (IS) development methodology encompasses the first three phases of the previously introduced AI system lifecycle: design, development, and deployment (see Figure 1). There are several commonly known methods for developing information systems, all of which have their own strengths and weaknesses (Dahlberg & Lagstedt, 2018). On a general level, these methods can be divided into two groups: plan-driven and change-driven methods (Lagstedt, 2019; Moe et al., 2012).

The plan-driven methods (such as the waterfall method) are divided into successive steps, such as system requirements, software requirements, analysis, program design, coding, testing, operations (implementation) (Royce, 1970). The following step proceeds only when the previous one has been completed. The use of plan-driven methods requires that the goals of the development and requirements of the IS can be identified with sufficient accuracy in advance. If there are large uncertainties in the goals, or the environment is volatile, there is a high risk of unnecessary and expensive work in the plan-driven method, when one has to return to the planning phase from the testing phase (Hansen & Lyytinen, 2010; Sommerville, 2011).

If the goal can be identified accurately enough in advance, the plan-driven method is a very straightforward and efficient method to achieve the desired result. In cases like these, a significant advantage of the plan-driven method is that it enables professionals in ethical deliberation to comprehensively assess the impacts and considerations as part of the design phase (Figure 1) well in advance of implementing any solutions. Additionally, the waterfall model typically features more extensive documentation, which aids in the traceability and evaluation of ethical decisions. However, if there is uncertainty about the goals, or if all stakeholders are not taken into account, there is a significant risk that the implemented system will not meet all needs, and ethics will not be taken into account sufficiently. The rigidity of the waterfall model poses challenges in addressing ethical concerns that arise in the post-design phase. Similar to other design errors, ethical issues are more difficult to rectify if identified at later stages.

The change-driven methods (such as agile) are iterative and incremental in nature, meaning that planning, development, and implementation are done in small steps (sprints). Between these steps, results and objectives are re-evaluated, and necessary changes are made to the objectives. As such, change-driven methods are especially suitable for situations where there are big uncertainties related to both business execution (the existing business processes and practices) and development objectives (Dahlberg & Lagstedt, 2021). However, change-driven development poses a high risk of unnecessary steps and extra work, and, in addition, it seems to be prone to technical issues as well (Behutiye et al., 2017; Holvitie et al., 2018).

When significant uncertainties are present in the development process, it is crucial to acknowledge that not all ethical considerations can be fully addressed during the design phase. Agile development facilitates the continuous review and updating of ethical issues in each sprint or iteration, allowing for prompt responses to emerging concerns. This incremental approach simplifies the evaluation and management of ethical impacts, thereby mitigating associated risks. Moreover, the ongoing involvement of stakeholders ensures the seamless integration of ethical perspectives. However, this integration is not automatic. Continuous development discussions, primarily and typically focused on desired functionalities, must ensure that ethical considerations are included and documented in all changes and new objectives.

In plan-driven development, the main responsibility of ethical considerations lies with domain experts (such as requirement engineers). Whereas, in change-driven development, the responsibility easily rests with end users, and the product owner must ensure that the ethical discussion remains on the agenda. The ethical considerations in AI development must encompass the entire lifecycle, transitioning seamlessly from development to usage. This transition from development to operations is a recognized challenge in information system development, where changes in responsible personnel can lead to information loss, and maintenance teams may struggle to understand development decisions, hindering essential updates. This issue is particularly critical in AI, where solutions are dynamic, often requiring regular dataset updates. Ensuring data reliability and ethical use during maintenance is crucial. DevOps is a collaborative approach that integrates software development (Dev) and IT operations (Ops) to automate and streamline the software delivery process, ensuring faster, more reliable releases through shared tools, practices (e.g., CI/CD), and continuous feedback (Ebert et al., 2016). This approach, which could be called AIDevOps, should also be applied to ethical considerations in AI development such that the discussions in the development phase must not be interrupted or lost when the responsibility is transferred to the maintenance of artificial intelligence systems.

3. Methods

Given the limited existing research on AI adoption in the public sector, we opted for a qualitative multiple-case study as our research approach. This design is particularly suitable for addressing research questions related to under-explored topics, where new insights are essential, and multiple cases improve the diversity of research data (Stewart, 2012). Multiple case studies apply this requirement as it aims to understand phenomena across organizational boundaries with several in-depth case descriptions (Gustafsson, 2017; Stewart, 2012). Thus, it provides a richer sample representing different types of organizations that the interviewees represent. To comprehensively explore this under-researched phenomenon, we conducted qualitative interviews with managers and experts working for the public sector processes from 19 organizations. By delving into their experiences, expectations, and perspectives, we aimed to gain a deeper understanding. Our study employed a qualitative interview research design, focusing on the design and development processes of AI systems - an area that is still in its early stages of exploration (c.f., Gummesson, 2000). The public sector plays a significant role in the Information and Communication Technology (ICT) market, and many private AI and ICT companies work for public sector organizations (Ghezzi & Mikkonen, 2023; Hickok, 2024). Thus, we selected the public sector as the target group of our multiple case study.

3.1. Participants

The interviewees comprised AI developers, digitalization experts, and managers from the public sector's digital services domain. They represent a crucial expert group actively involved in digitization processes and AI adoption. Thus, their participation significantly enhances the study's validity. The interviews were conducted with 20 representatives from 19 organizations in Finland. These organizations included municipalities, government agencies, educational institutions, and private companies that provide services to the public sector (see Table 1). Our selection of case companies followed principles aimed at ensuring rich samples of real-world phenomena (Eisenhardt & Graebner, 2007). Specifically, we chose organizations that were recognized as leading AI adopters in the public sector or were recommended as such. Additionally, we focused on organizations dealing with large volumes of tasks, as the value potential for AI is particularly significant in such cases. Thus, the selection criterion was based more on AI adoption experience or data volume rather than the size of the organization.

Table 1. The interviewees, their affiliations, and organization types

	Position of Interviewee	Organization Type	Size	Case No
1	Expert	Educational Organization	Medium	16
2	Expert	Educational Organization	Small	14
3	Middle Management	City Organization	Large	2, 5, 6
4	Middle Management	City Organization	Medium	4, 7
5	Middle Management	Government Organization	Large	9, 11
6	Middle Management	Government Organization	Small	8, 10
7	Middle Management	Ministry	Large	12
8	Middle Management	Private Organization Solving Public Needs	Small	19
9	Top Management	City Organization	Large	3
10	Top Management	City Organization	Medium	1
11	Top Management	Educational Organization	Small	15, 17A, 17B
12	Top Management	Ministry	Medium	13
13	Top Management	Private Organization Solving Public Needs	Large	18

3.2. Data collection

The research data was collected from interviews with 19 case organizations that are working for public or government services in Finland. We selected individuals for interviews who were experts in the adoption of AI or in digital transformation within the public sector and thus could offer significant insights into this phenomenon. Hence, the interviewees represented ministries, cities, governmental organizations, educational institutions, and private organizations working for the public sector.

The researcher contacted the potential interviewees via email, outlining the study's objectives and seeking their willingness to participate. After obtaining informed consent, the researcher scheduled interview sessions and conducted interviews via Microsoft Teams, with an average duration of 45 minutes. Each session was video-recorded and automatically transcribed by Microsoft Teams. Additionally, one interview was conducted in a face-to-face setting.

The methodological approach employed semi-structured interviews (Appendix 1), wherein the researcher predetermined the main themes based on the research questions. The prior literature on AI adoption guided us to determine the themes of the interview script. The semi-structured interview methods allow for versatile and flexible data collection practices (Kallio et al., 2016). Thus, the flow of discussion within each interview session remained flexible, allowing exploration of those topics. The data analysis for this study focused on descriptions and comments related to ethical considerations in the design, deployment, and use of AI within public sector processes and tasks, or those closely associated with it. In addition, we were interested in the interviewees' views on research and development methods, processes, obstacles, opportunities, and best practices of AI adoption.

3.3. Data Analysis

The data analysis followed the principles of qualitative content analysis (Schreier, 2012). More specifically, the inductive grounded theory approach (Strauss & Corbin, 1998) was applied in data analysis and in forming new theoretical understanding. We initiated the analysis of transcribed interviews by identifying relevant excerpts based on our research themes. We applied three coding phases: open, axial, and selective (Matavire & Brown, 2013; Strauss & Corbin, 1998). During the initial round, we applied initial codes related to the AI development process and trustworthiness and ethics that were so-called sensitizing devices for us (cf. (Matavire & Brown, 2013). We annotated all comments that mentioned or explained these initial codes and their associated themes. All other material was excluded from the research data of this study. During the first coding phase, we transferred the initial relevant excerpts to a Word document, where we further organized them into smaller sub-categories based on their content. In this first coding round, we followed the principles of data-driven open coding and re-coded excerpts without predefined categories (Strauss & Corbin, 1998). In this coding phase, the role and significance of ethical issues as part of the AI development and adoption process began to crystallize.

In the second axial coding round, we created continuous improvements and categories, and drew inspiration during the data analysis, continuously moving back and forth between our data and emerging theoretical understanding (Mattarelli et al., 2013). Our data included experiences, thoughts, and insights from all phases of AI design, development, and adoption. Some of the interviewees held leadership positions in their organization's AI development, while others worked with the implementation of AI.

In the third coding phase, the results were organized into groups based on their content, from which six categories eventually emerged. In this selective analysis phase, selective coding was applied, and it resulted in six following categories: i) ethical competence becomes a key competence, ii) the ethical competence belongs to the design of AI, iii) ethical considerations begin from the requirement specification, iv) designing of human-aligned AI, v) AI solutions require careful monitoring for trustworthiness, and vi) ethical requirements vary depending on the use case. We noticed that these categories have interrelationships and dependencies with each other and follow the lifecycle and development stages of AI. We conceptualized the findings in Figure 2.

We are aware that qualitative analysis may have limitations in interpreting interview transcripts (Eisenhardt & Graebner, 2007). From the data analysis perspective, another researcher checked that the interview excerpts extracted from the interview transcripts were correctly classified into the six emerging categories and were aligned with the interview data and prior literature. We also used the ethics of AI guideline documents for strengthening evidence (see Chapter 4.1). To enhance the trustworthiness of our data analysis, we also connected our findings to existing literature. We used prior literature as a sensitizing device aligned with the evolved grounded theory approach (Matavire & Brown, 2013). Specifically, we continuously reviewed and critically reflected on our theoretical understanding of empirical findings by examining prior literature on AI adoption and development (Gummesson, 2000). In creating a new theoretical understanding from the results, we employed an abductive and iterative approach (Dubois & Gadde, 2002) which allowed us to establish explanations regarding the ethical development methods of AI. By iteratively comparing prior research with new insights from our results, we were able to make a novel theoretical contribution to the existing field. Ultimately, this abductive and iterative approach deepened our understanding of the data while simultaneously advancing the theoretical understanding of ethical AI development (Gummesson, 2000).

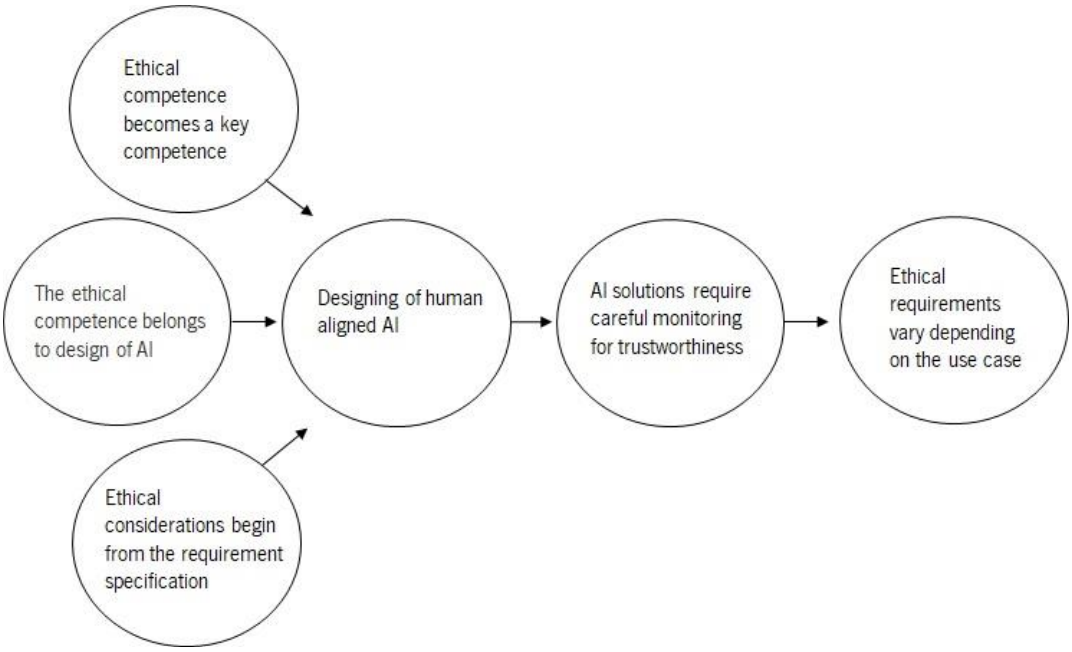

Fig. 2. The conceptual model of the key findings

4. Findings

4.1. Ethical competence becomes a key competence

The findings show that ethics plays a crucial role in designing, developing, and adopting AI. The designers, developers, and adopters should be able to manage those risks. For example, AI applications must be designed to prevent delving too deeply into personal data. They should also avoid revealing excessive information about individuals. These considerations are essential when planning and defining AI applications.

> *As we delve deeper into an individual's data, we start encountering quite personal information about their health and other aspects (Case 15).*
>
> *There can be ethical questions, but, well, they are not obstacles (Case 5).*

In addition to privacy, reliability is a crucial requirement when defining and designing AI applications. Reliability also impacts privacy because a dependable application is inherently secure. One interviewee pointed out that AI can start analyzing aspects beyond its original design or initial need. This represents a key risk in AI, as reliable and secure solutions are specifically tailored to address specific needs and are used accordingly. Thus, designers, developers, and adopters should have the competence to manage their AI-related actions.

> *If we speak about the adoption of technology to social and healthcare services, there are pretty much such attitudes, like ethical questions. (Case 6).*
>
> *Now, one thing is precisely this: one should understand what one is doing, because otherwise we have artificial intelligence that models something entirely different. AI solves a different problem based on its intended use (Case 16).*
>
> *Who is responsible if an artificial intelligence makes a mistake? Is it the person using the AI, or is it the developers who customized the AI, there can be risks realized, and many may hesitate to offer AI development if the legal boundaries are unclear (Case 18).*

Some public organizations (see e.g. Finnish Tax Administration, Ministry of Finance, Suomi.fi) have also published their ethical guidelines for AI, where they emphasize its importance in developing, adopting, and using AI.

4.2. AI systems should support users' ethical evaluation

The users and developers are learning to manage human-AI interaction from an ethical viewpoint. The informants stated that ethical questions or at least some doubts about the reliability of results always persist.

> *All models are inherently biased to some extent, so perhaps we should also have some form of tolerance for that. Often, people imagine that when we have an AI solution, it must always be one hundred percent right in all situations or surpass human capabilities for there to be some benefit from it (Case 9).*

Improving transparency of AI functionality and results through explainable AI was emphasized. This addresses ethical considerations where users can see the rationale of AI's decisions, leading to enhanced trustworthiness. This implies that evaluating the ethics of AI applications should be a shared responsibility, involving not only designers and developers but also the users themselves. Transparency and explainability of AI applications support this need.

> *Certainly, we should be able to evaluate precisely why artificial intelligence has arrived at a particular solution. In this one point, you might also consider the flip side: why it hasn't arrived at a different solution. Transparency is undoubtedly crucial in this regard (Case 9).*
>
> *Our big dream is to get AI for analyzing result data, so that we can see beyond the numbers (Case 15).*

4.3. The ethical competence belongs to the design of AI

Ethical competence should be part of employees' competencies. It is challenging to introduce ethical competence externally during the development process; thus, it should be built within the organization's capabilities, and some kind of ethical AIDevOps practices should be applied (see section 2.2). When designing and developing AI, ethics cannot be disregarded, as it is an essential aspect of modern AI phenomena. Hence, the ethics of AI is not only the requirement of responsible AI usage, but it also belongs to the design and development of AI systems (see Section 2.1).

> *Regarding these new AI solutions, I would perhaps add that we need individuals with expertise in AI ethics, because, currently, it's challenging to separate discussions about AI from ethical considerations (Case 9).*
>
> *Like, an assessment should be done already during the development preparation. And of course, also before implementation. If something has changed, we have an AI ethics group that kind of oversees things (Case 9).*

Evaluating ethical consequences or requirements is not an easy task, as it might be context dependent. Sometimes there are "gray areas" which require careful ethical considerations. In addition, developers, as well as end users, are concerned about accountability in cases when AI produces the wrong output. Therefore, accountability is an important pillar of the ethical AI framework and has been addressed by many ethical AI frameworks mentioned in Section 2.

> *In order for that student, for example, to be supported and guided, and for their studies to progress and everything else there. There are also many gray areas there, regarding what is meant or not to meant by fairly vague instructions, regulations, or laws, is a somewhat case-specific matter (Case 14).*

4.4. Ethical considerations begin from the requirement specification of the AI application

Ethical considerations are not solely related to the use and adoption of AI. When designing and developing AI solutions, we must assess how the combination of specific datasets might reveal information about individuals. For instance, a city organization could potentially gather substantial information about individuals if the data collected across different departments and areas were to be interconnected. This relates to the responsibility of AI developers and administrators of how they are using a large set of data with the offered AI systems. Thus, this consideration begins in the early phases of AI design, namely in the requirement specification.

> *But then, in this context of artificial intelligence, cities easily face significant challenge, and it is that basically like cities know much about individuals, and we arrive at the issue of where is the ethics of AI going on, and where we are using it, and there comes unruly situations (Case 3).*

One way to mitigate ethical risks in public sector AI projects is to select use cases that do not directly impact individuals but rather focus on the built environment, such as infrastructure and the physical environment.

> *Would it be the safest approach for cities regarding the utilization of artificial intelligence to initially apply it in areas where the actions do not directly impact people but rather relate to physical environments, transportation networks, building infrastructure, and natural areas and beyond (Case 3).*

> *Somewhat, I believe that when it comes to numerical data, the more unambiguous the initial information collected, the more reliable the results that artificial intelligence can produce (Case 19).*

4.5. Designing of human-aligned AI

Designing human-aligned AI applications requires the involvement of end-users in the design and development phases. This way, the designers and developers can iteratively test new AI applications and improve them based on the feedback. This user-centered design approach increases the ethical capabilities of the AI systems.

> *We tested it with a few users, and it soon became clear that they doubted where this 'guess box' was getting its 'good or bad' or 'accept or reject' decisions from. We figured it out and implemented explainable AI, which actually helped (Case 8).*

Design capability was emphasized. An informant of an advanced AI adopter organization pointed out that we should be able to design human-centric AI applications. This does not refer to a service design process, but to AI applications that are context-aware and human-aligned AI systems. Organizations should manage those design capabilities at a strategic level, as human centricity is a non-functional requirement that should be raised to a requirement in the early phases of design processes.

> *We increasingly understand the environment and humans, particularly human orientation. And we integrate these more and more, and the human orientation connected to the capabilities created by technology and its transformation. And our aim is to continually strengthen that at a very strategic level (Case 11).*

This is a management challenge of AI development, as the developers should be able to review design goals from a broader perspective than technological opportunities. Putting humans and usage context at the center of the design processes requires strategic changes in the management of AI adoption and development.

4.6. AI solutions require careful monitoring for trustworthiness

Unlike conventional software, the functioning of AI solutions might change. AI solutions or their algorithms require training with data before they are ready for use. This is in stark contrast to conventional software, which is considered 'ready-made' once it has undergone testing and is put into production use. Conventional software operates consistently, regardless of the volume of data it processes, adhering to its pre-programmed logic. However, it does not adapt its output based on new information flowing through it. In contrast, AI algorithms dynamically analyze data, adjusting their output based on the information in the data. Unfortunately, this adaptability can lead to gradual biases or discriminatory behavior in AI solutions, even if initial tests align with expert perspectives. This makes significant changes to the development and maintenance processes of AI solutions compared to conventional software maintenance in organizations. In addition, organizational restructuring might also create privacy risks if the access rights of AI systems are changed accordingly. The robustness of AI models is also an important property that refers to maintaining a decent performance for varying inputs and scenarios. This is particularly important for sensitive applications where a wrong prediction could have drastic consequences. At the same time, this also comes up as one of the major concerns or requirements of the end users.

> *If we had an AI model that, for instance, made decisions, we would need to monitor the behavior of this AI model to ensure that it doesn't exhibit any drift, so that it should consistently make decisions in a similar manner over time, or it does not learn discriminatory tendencies or other undesirable traits we need to actively monitor regarding to these models, especially when considering ethical aspects or similar ones. Perhaps this falls within the domain of expertise for ML engineers, addressing areas that traditional development processes often overlook (Case 9).*

In addition to technological challenges, organizational structures might also affect the ethical use of AI or ensure its trustworthiness.

> *This caused, once again, an administrative boundary where suddenly they couldn't access anything, almost like they were in the dark, unable to see anything, when previously, they had been able to get so with certain restricted rights (Case 14).*

The target of AI development moves constantly. A challenge in developing AI solutions is that AI technologies are developing at an enormous speed. Thus, the requirement specification may be outdated when a slow implementation process starts, as new models and methods may have been released during the definition and design phases. Hence, an ethical AI system today is not necessarily ethical tomorrow.

> *If we look at history, it's true that symbolic AI is now in an AI winter, while computational AI, you know. Deep learning networks are now mainstream (Case 9).*

4.7. AI-enhanced application categories – different contexts for ethics of AI

Organizations use AI for a number of applications including financial management systems, processing applications, predicting customer demand, anticipating the progress of studies, customer service, or monitoring visitor flows. Some have already integrated generative AI into the intranet, but it is largely embedded in office applications. Table 2 lists the AI applications that the interviewees mention to have or are going to have. Based on the lists and how they produce value for the organization, we clustered the applications into eight categories.

Table 2 shows that AI applications are associated with different processes, user groups, and usage contexts. In designing, developing, and deploying AI applications, we should review the special needs of processes, users, and the environment where AI applications will be used.

Table 2. AI-based information system categories found in the case organizations

AI-based application examples that the interviewees mentioned	AI-based information system category	Description
Predicting dropouts, predicting customer demand	Management AI	Assist in predicting needs or risk factors. Increased efficiency and productivity.
Financial process automation, proposal evaluation	Administration AI	Automation and optimization of administrative processes. Reduced costs.
Study planning, competence profiling, thesis planning support	Educational AI	Management support for educators and administration. Learning support for students.
Border control, waste container indicator, cleaning robot	Operative AI	Automation of the monitoring of routine tasks. Reduced costs.
Large language models such as ChatGPT for assisting knowledge work, automatic transcript, and generative AI embedded in the intranet	Office AI	Knowledge support for experts. Assist in routine tasks by saving time and resources.
Chatbot, customer feedback	Communication AI	24/7 services for customers. Assist in improving customer experience.
Software robotic in financial processes, email filtering, application classifier, a predictor of visitor flow, scanned document reader	Transactional AI	Automation and optimization of experts' workload. Reduced costs.
Traffic management, Internet of Things in a city infrastructure	Infrastructure AI	Automation and optimization of monitoring processes. Improved decision-making.

5. Discussion

This study identified six interrelated phenomena of AI ethics during the AI lifecycle (Table 3). Some of them are related to the organization's AI design and development capabilities and practices, while others are related to the adoption and use of AI. AI ethics is often thought to be related to the adoption of AI, and many ethical guidelines for AI focus on the adoption and usage phases rather than AI design and development. However, this study shows that AI ethics is also part of the organization's design and development capabilities. Thus, it also relates to the design and development processes, in addition to activities during adoption and use.

This study has several theoretical contributions. First, we expanded the ethical discussion of AI to include the design and development process of AI systems. Prior research on the ethics of AI has mainly focused on AI adoption, whereas the perspectives of design and development processes have remained scarcer. Also, we should focus on ethical considerations throughout the entire AI system lifecycle, not only from the viewpoint of AI adoption and usage. Our study is grounded in empirical evidence where participants validate the findings. Ethical considerations are particularly important from the initial phases as they lay the groundwork for the whole AI adoption and usage processes. This study further indicates that ethical considerations are relevant to every role involved in the AI system lifecycle. All actors within the lifecycle of AI applications should be engaged with ethical considerations. Moreover, different use cases set various requirements for ethical considerations since organizations and usage environments may raise special requirements. Consequently, this study contributes to the debate on ethical AI system design from the life cycle perspective of AI applications.

Our second contribution is to the design, development, and adoption of AI in the public sector, as our results particularly reflect the views of AI adopters in this sector. Existing studies (Misra et al., 2023; Neumann et al., 2024) demonstrate that AI is a significant technological enabler for developing public management practices and processes. For instance, city and government organizations could potentially gather substantial information about individuals if the data collected across different service sectors were to be interconnected. Public sector organizations often process large data flows and have significantly large data sets that provide an excellent starting point for automation. Public sector organizations have large amounts of data that do not directly impact individuals but rather focus on the built environment, such as infrastructure and the physical environment. In those cases, the ethical risk is lower.

The third contribution shows that ethical consideration is not only a single task in AI adoption, but it is an integral requirement from the design to the implementation and use of AI. Unlike conventional software systems, AI adapts to the situational environment and continuously uses data to enhance its performance. Hence, ethical risks and the trustworthiness of its results require continuous monitoring by AI adopters. Advancements in AI technologies and data management practices boost the development of more advanced, ethical, and trustworthy AI solutions. The frameworks for the ethical design of AI systems (Vakkuri & others, 2021) also lower design and development barriers to designing new ethical AI solutions. Prior studies (e.g. (Kaniadakis & Linturn, 2022)) emphasize the crucial role of interdisciplinary teams in technology adoption, who search for, define, and solve development challenges and opportunities. Our study extends this remark to all phases of the AI lifecycle, where interdisciplinary competencies play an essential role

The fourth contribution of this study (see Table 3) shows that ethical considerations regarding AI design and deployment should begin from the resourcing of the design team with persons with ethical competence, as several foundational decisions are made before the beginning of the development processes. This is consistent with the study by Smith (2019) which highlights the need for diverse teams, including members with ethical competence, to guide the development of trustworthy AI systems. Additionally, the findings reveal that ethical competence should be a part of AI-related design competencies and thus, an integral part of the design process. This is in line with IBM's AI design ethics overview which emphasizes that an ethical, human-centric AI must be developed in a manner consistent with the values and ethical standards of the affected community. Furthermore, the ethical design of AI relates to the designing of human-aligned AI. Human-aligned AI is both ethical and human-centric AI supporting human autonomy and trustworthy decision-making. This finding aligns with the study of He et al. (2021), who advocate for a human-centric AI framework that integrates high levels of human control with advanced automation. Our findings underscored the importance of design competence in AI, especially as human-aligned AI becomes increasingly central to its adoption. It is consistent with the study by Tjondronegoro et al. (2022) which highlights the importance of integrating ethical considerations throughout AI development, and by Goyal et al. (2024) which highlights the need for understanding human expectations in designing AI agents, emphasizing that aligning AI behaviour with user preferences is crucial for effective human-AI collaboration.

Unlike conventional software systems, AI solutions require careful monitoring of trustworthiness as they are continually learning and evolving systems. As the final construct, AI systems should support users' ethical evaluation while using AI applications. The demand for explainability as a part of AI systems supports this requirement. This finding is supported by Shin's (2021) empirical work that demonstrates that explainability promotes trust and empowers users to ethically engage with AI systems, supporting the need for user-centric explanatory interfaces.

The fifth contribution of this study relates to AI applications in the public sector. Based on the findings (Table 2), we conceptualized eight AI-based information system categories. The AI-based system categories have unique use cases and value propositions. Transactional AI and infrastructure AI create the basis and operating platforms for other information systems, whereas office AI, communication AI, educational AI, and management AI focus more on end-user value co-creation. Administration AI typically supports administrative processes in internal or cross-institutional reporting and monitoring needs. From the ethical viewpoint, all eight categories have their specific ethical risks depending on the data they are analyzing and managing, and their role in decision-making. Transactional AI, infrastructure AI, and office AI do not directly generate content and results that are directly associated with ethical issues, unlike educational AI and management AI, which are more related to human decisions and recommendations. However, all those categories should meet the requirements of trustworthy AI, which is a part of ethical principles.

Table 3. The role of ethics in designing and developing AI applications

Key findings	Explanation	Actions	Phase of lifecycle
Ethical competence becomes a key competence	Competence to define ethical requirements is a critical skill in AI projects	Ethical competence is a resource that should be included in the project plan	Design
Ethical competence belongs to the design of AI	Ethical consideration is a crucial part of the design phase	The design team should have a person who has the knowledge and skills to define ethical requirements	Design Develop
Ethical considerations begin with the requirement specification	Ethical consideration should begin in the early phases of an AI project when requirements for an AI application are defined	Ethics of AI is a non-functional requirement that affects other functional requirements in the specification of the AI application	Design Develop
Designing of human-aligned AI	Designing human-aligned AI applications includes the implementation of ethical requirements	The fulfillment of ethical requirements should be tested to ensure the AI application meets the principles of human-aligned AI application	Design Develop
AI solutions require careful monitoring for trustworthiness	The ability of AI applications to function ethically is associated with their continuous trustworthiness	The functions of explainability and human-in-the-loop ensure that AI applications generate ethically sustainable results	Operate
Ethical requirements vary depending on the use case	Ethical requirements are associated with the usage context of AI and thus they are context-dependent	The use case and usage context of an AI application affect the sensitivity of data that the AI application analyses, generates, and manages.	Deploy Operate Retire

The study found what ethical issues are emphasized as part of AI system development and adoption in case organizations. We summarized the findings in Table 3, which emphasizes the integration of ethical issues in all phases of the AI design and development process. This study emphasizes the role of ethical issues in the requirement specification where the most important ethical selections are made. Additionally, ethical competence should be seen as a key competence in AI design and development teams, as it is an integral part of AI models, data, and systems. More specifically, all ethical considerations are not associated with the usage and implementation phases of AI, but many fundamental decisions regarding ethics are made in the design and development phases of AI systems. In addition, it is important that the ethical discussion is not interrupted when moving from the development phase to the maintenance phase. To support this continuity, there is a need for ethical AIDevOps practices that integrate ethics into the entire AI lifecycle. What kind of AIDevOps practices should be in place to best support an ethical continuum throughout the entire lifecycle is an important subject for further research.

This study examined how ethical considerations should be integrated into AI development processes. Based on the findings, we further analyzed their implications for organizations, as well as for AI design and development practices, and ethical considerations. This study points out that rapidly developing AI technologies, system components, data sets, and AI models challenge the design and development processes from technical and ethical perspectives. AI design and development is a more complex process than designing conventional software systems. Consequently, it requires more ethical design competencies and multidisciplinary collaboration from various levels of an organization.

6. Limitations and future research agenda

The scope of the study was limited to public sector organizations in Finland, which may affect the generalizability of the findings. While the study provides an in-depth analysis of AI ethical challenges within this specific context, the ethical considerations and development practices may vary across different regions, cultural settings, and public sector environments.

The study relied on qualitative interviews as the primary data collection method. Although this approach allowed us to capture rich, detailed insights into the ethical challenges faced by public sector organizations, it also introduces potential biases. The subjective nature of interviews means that findings are shaped by the perspectives of the interviewees, and there is a risk that some ethical concerns may not have been fully disclosed or emphasized during the interviews. Especially, considering the AI lifecycle shown in Figure 1, it is evident that ethical considerations encompass the whole AI lifecycle which is much deeper than commonly understood. In contrast, the interviewees often see only a part of the AI lifecycle; therefore, their point of view may be limited. That said, it is still important to analyze their opinions as they are the major stakeholder of this system.

The dynamic nature of AI technologies presents a challenge for capturing the rapidly evolving ethical issues associated with AI adoption. AI technologies particularly generative AI and large language models are advancing at an unprecedented rate, and ethical concerns may shift as these technologies become more sophisticated and embedded into public sector systems. As a result, some ethical challenges discussed in this study may become outdated or less relevant as new AI models and frameworks emerge.

Future studies could expand the scope of this study to include private and public sector organizations from different regions or countries, allowing for a comparative analysis of ethical AI challenges and best practices across diverse socio-political contexts. Additionally, quantitative research could be conducted to measure the impact of ethical AI adoption on organizational performance and trustworthiness from both employees' and citizens' perspectives. Investigating the long-term effects of ethical AI systems on public services would also provide deeper insights into how continuous ethical monitoring can sustain trust in AI over time. Moreover, continuous research is needed to address the evolving challenges and ensure that ethical guidelines remain applicable and effective.

Future research should adopt a more comprehensive, lifecycle-oriented approach to examining AI ethics. A holistic perspective across the entire AI lifecycle, including design, development, implementation, operation, and retirement phases, can offer deeper insights into the cumulative ethical impacts. Such an approach could reveal critical interactions between phases that influence ethical outcomes, such as the long-term effects of design choices on model robustness and accountability in later stages.

7. Conclusions

This study contributes to the growing body of knowledge on ethical AI development by exploring the challenges faced by public sector organizations. Our findings highlight the importance of integrating ethical considerations into every stage of the AI system lifecycle, from the initial design and development phases to deployment, monitoring, and retirement. By utilizing empirical data from multiple public sector case organizations in Finland, we have provided both theoretical insights and practical guidelines for developing ethically aligned AI systems.

We emphasize the need for a comprehensive, lifecycle-oriented approach to ethical AI development. The AI lifecycle spans various phases that collectively shape the ethical impact of AI applications. Addressing ethical concerns at each stage ensures that foundational principles like transparency, accountability, and fairness are not just design concepts but integral components that guide the system's behavior over time. By embedding ethical practices throughout the lifecycle, organizations can anticipate and mitigate risks more effectively, which will lead to greater trust and reliability in AI solutions. This holistic perspective is especially relevant to the public sector, where AI systems directly impact citizen well-being and must align with public values. Therefore, prioritizing lifecycle-wide ethical considerations to support sustainable, responsible, and human-centered AI applications is very important.

From a scientific literature perspective, this study adds to the limited empirical research on ethical AI development in the public sector. While much of the existing literature has focused on high-level principles and frameworks, this research offers concrete, real-world insights into what ethical considerations should be integrated into AI development processes. The study highlights the importance of ethical competence as a core skill within AI design teams, emphasizing that ethics cannot be treated as an afterthought but must be embedded throughout the AI lifecycle. This contribution is particularly significant for public sector organizations, where trust, transparency, and fairness are critical due to the direct impact of AI systems on citizens and public services.

For practitioners, our research provides actionable recommendations on how to incorporate ethical guidelines into AI projects, addressing issues such as human alignment, accountability, transparency, and the continuous monitoring of AI systems. These recommendations can guide AI developers and managers in making more informed decisions about ethical risks and responsibilities in AI deployment.

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Appendix 1

The interview script (semi-structured interview)

1. What is the current state of AI application?
2. What opportunities do you see? Which processes could benefit from it?
3. What obstacles are there to AI adoption?
4. What would be the minimum level of expertise required in the organization at different levels when implementing AI solutions?
5. What collaboration should take place between different departments when implementing AI?
6. What kind of task volumes do you have and how are they managed? Where are they located, who is responsible, and could they be optimized with AI?
7. What ethical or reliability issues related to AI have you observed or should be considered?

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RESEARCH ARTICLE

Contribution of big data analytics to risks and disruptions mitigation and agility performance

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Abstract
The main objective of this study is to understand the mechanisms by which supply chain data analytics (SCDA) capabilities impact supply chain agility performance (SCAP) directly or through the mediation of other capabilities, particularly supply chain risk mitigation (SCRMI), supply chain robustness (SCROB), and supply chain resilience (SCRES). The study is based on survey data collected from 203 foreign companies in global value chains located in Morocco's industrial acceleration zones, whose legal status is assimilated to foreign territory. Respondents were mainly senior and middle managers with experience in general management and operations and supply chain management. Validity and reliability analyses as well as hypothesis testing were performed through structural equation modeling (SEM) using SPSS Amos. The results showed that SCDA capabilities strengthen the capabilities of SCRMI, SCROB, and SCRES and indirectly improve SCAP through partial and exclusive mediation of SCRES capability. The results of this study revealed the importance of developing SCDA capabilities for strengthening risks and disruptions mitigation capabilities and improving SCAP. Also, optimizing the return on investment in SCDA capabilities should incorporate dedicated risks and disruptions mitigation tools and alerts to facilitate supply chain managers' decision making in this area.

Keywords
data analytics; risks; disruptions; mitigation; robustness; resilience; agility.

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1. Introduction

Today's supply chains are long and complex, making them unpredictably vulnerable to risks and disruptions (Scheibe & Blackhurst, 2019). The effects of disruptions can be transmitted to other regions and supply chain actors (Ivanov et al., 2014). Consequently, disruptive risks represent a new challenge for supply chain managers (Ivanov & Dolgui, 2019). To this end, it is essential to develop supply chain data analytics (SCDA) capabilities to improve those of supply chain risk mitigation (SCRMI), supply chain robustness (SCROB) and supply chain resilience (SCRES) and, ultimately, to directly and indirectly improve supply chain agility performance (SCAP).

However, supply chain managers can only effectively control and manage risks, including disruptive ones, if supply chain visibility is improved and real-time information is available (Bag et al., 2020). As such, supply chain partners can take advantage of technologies dedicated to data analytics, to prevent disruptive risks and monitor their propagation (Kamble & Gunasekaran, 2020).

In view of the above, data analytics is one of the opportunities offered by the technological environment, which could be seized to generate business value for companies (Chen et al., 2012). Supply chain partners invest in data analytics to reduce costs and uncertainties and improve their decision-making capability (Kache & Seuring, 2017), all with a view to gaining competitive advantage (Wamba et al., 2017).

In addition, data analytics involves the extraction, diagnosis, integration and transformation of supply chain data into valuable information and meaningful models for decision-makers (Tiwari et al., 2018). Data analytics can boost partners' agility performance (Wang et al., 2016), while providing insights and predictive models that can improve risks and disruptions mitigation capabilities in the supply chain (Shamout, 2021). Also, accurate and timely data combined with data analytics can generate or reconfigure risk mitigation, resilience and robustness capabilities.

The literature on the potential impact of data analytics capabilities on performance seems to have grown in recent years. According to researchers, the effects of data analytics capabilities on performance are indirect and therefore mediated by other organizational capabilities (Mikalef et al., 2020). To this end, it seems important to conduct further empirical researches on the mechanisms by which data analytics capabilities contribute to improving agility performance (Mikalef et al., 2020).

In response to calls for further research in the field of operations and supply chain management, this study is one of the first to explore the mechanisms by which data analytics and risk mitigation capabilities interact and contribute to improved agility performance, in the presence of risks and disruptions generated by changes and uncertainties in the business environment.

In light of the above, the main objective of this study is to understand the mechanisms by which data analytics capabilities impact agility performance, either directly or through the mediation of other capabilities, specifically those of risk mitigation, robustness and resilience. Indeed, this study aims to fill this gap by answering the following research questions (RQs):

- RQ1. What are the effects of supply chain data analytics capabilities on strengthening risk management capabilities, particularly risk mitigation, robustness and resilience?
- Q2. How do these data analytics, risk mitigation, robustness and resilience capabilities interact to improve supply chain agility performance?

This paper responds to a specific call by describing the direct effects of data analytics capabilities on agility performance, risk mitigation, robustness and resilience, as well as its indirect effects on this agility performance through the mediation of robustness and resilience capabilities. Then, the direct effects of risk mitigation capability on robustness and resilience as well as their effects on agility performance were investigated, using the knowledge-based view as a theoretical basis. This being said, this paper attempts to shed new light on data analytics capabilities and its contribution to improving operational and disruptive risk management capabilities, particularly those of risk mitigation, robustness and resilience, as well as their joint contribution to improving agility performance.

This document is organized into six sections. Following the introduction, section 2 presents the theoretical background. Section 3 presents the hypothesis development. The methodology is described in section 4. The results and their theoretical and managerial implications are presented and discussed in section 5. Future directions and the main limitations of the research are announced in section 6.

2. Theoretical background

2.1. knowledge-based view

The knowledge-based view asserts that companies excel through the effective use of knowledge rather than its exclusive possession. Indeed, the capability of the company or supply chain to capture, process and disseminate knowledge appears to be more important in differentiating itself from the competition (Blome et al., 2014; Wang et al., 2024). To this end, data analytics can enrich the knowledge base and, consequently, improve both non-disruptive and disruptive risk mitigation capabilities to achieve competitive advantage (Dubey et al., 2019; Cooper et al., 2023).

Furthermore, the knowledge-based view holds that improving knowledge flows reduces uncertainty (Bode et al., 2011). In this respect, supply chain partners exchange knowledge as part of effective cooperation in various areas, including risks and disruptions management (Kong et al., 2020). In this respect, data analytics enables the effective use of knowledge related to risk prevention, identification and assessment, which in turn should strengthen risk management capabilities, particularly those of risk mitigation, robustness and resilience. Indeed, the knowledge-based view has been adopted as the theoretical basis for developing and testing the research model.

2.2. Supply chain data analytics

Supply chain data analytics (SCDA) has been identified by the use of descriptive, predictive and prescriptive methodologies in supply chain planning, procurement, manufacturing and delivery operations (Souza, 2014). Consequently, supply chain risk management (SCRM) is one of the areas where data analytics could be highly beneficial (Saleem et al., 2021; Khan et al., 2023).

Many researchers believe that data analytics enables supply chain partners to capture, integrate, deploy and analyze large quantities of big data, which could give them a competitive advantage (Khan et al., 2023). Data analytics capabilities enable more effective perception and analysis of external developments (Dubey et al., 2018). Having the capabilities to collect, analyze, and synthesize data will enable partners to develop effective and correct plans and policies, which are critical to assigning supply chain a competitive advantage in a dynamic and uncertain business environment (Wamba et al., 2017; Khan et al., 2023). In addition, data analytics involves the use of past and present data analysis tools for predictive modeling that can improve agility performance (Shamout, 2019). These data analytics tools reduce costs, risks, and improve the speed and accuracy of decisions (Kache & Seuring, 2017). The knowledge-based view postulates that knowledge can enable companies as well as supply chains to achieve long-term competitive advantage. In addition, research has shown that SCDA contributes to improved visibility, resilience and robustness and, ultimately, agility performance (Schoenherr & Speier-Pero, 2015).

2.3. Supply chain risk management

In a bid to improve supply chain network management, develop a competitive advantage and reduce the impact of risks and disruptions due to global events, organizations have sought to develop strategic and operational capabilities, particularly SCDA (Park & Singh, 2023).

Some researchers have attempted to examine how SCDA capabilities enable organizations to better manage risks in their supply chains (Park & Singh, 2023). Park & Singh (2023) argue that organizations can develop their resilience capability by leveraging SCDA, thereby mitigating disruptions in their supply chains and positively impacting business performance. Similarly, SCDA capabilities enhance the risk mitigation capability of supply chain partners, enabling them to specifically identify and respond to non-disruptive risks in a timely manner (Park & Singh, 2023). In addition, the development of SCDA capabilities leads to an improvement in the company's capability to perceive changes in the internal and external environment that could potentially create a disruptive event in its supply chain network (Wamba et al., 2020). Similarly, Modgil et al (2021) have argued that SCDA enhances the sensing and sense-making capabilities within an organization. Indeed, once potential points of concern appear in the company's supply chain network, SCDA creates and transmits knowledge that enables the company to develop risk mitigation, robustness and resilience capabilities (Park & Singh, 2023). Furthermore, Spieske and Birkel (2021) examined how SCDA enables companies to develop risk management capabilities. Furthermore, Vieira et al. (2020) have argued that big data supported by analytics tools can be used effectively to predict all potential risks, including those that disrupt the supply chain and, subsequently, enhance the risk mitigation, robustness and resilience of the entire supply chain (Vieira et al., 2020; Park & Singh, 2023). To this end, this work uses the knowledge-based view to understand how SCDA capabilities could enable organizations to generate or reconfigure other capabilities dedicated to risk mitigation, robustness and resilience, and to predict risks and disruptions before they occur in the supply chain.

3. Hypothesis development

Figure 1 presents our research model.

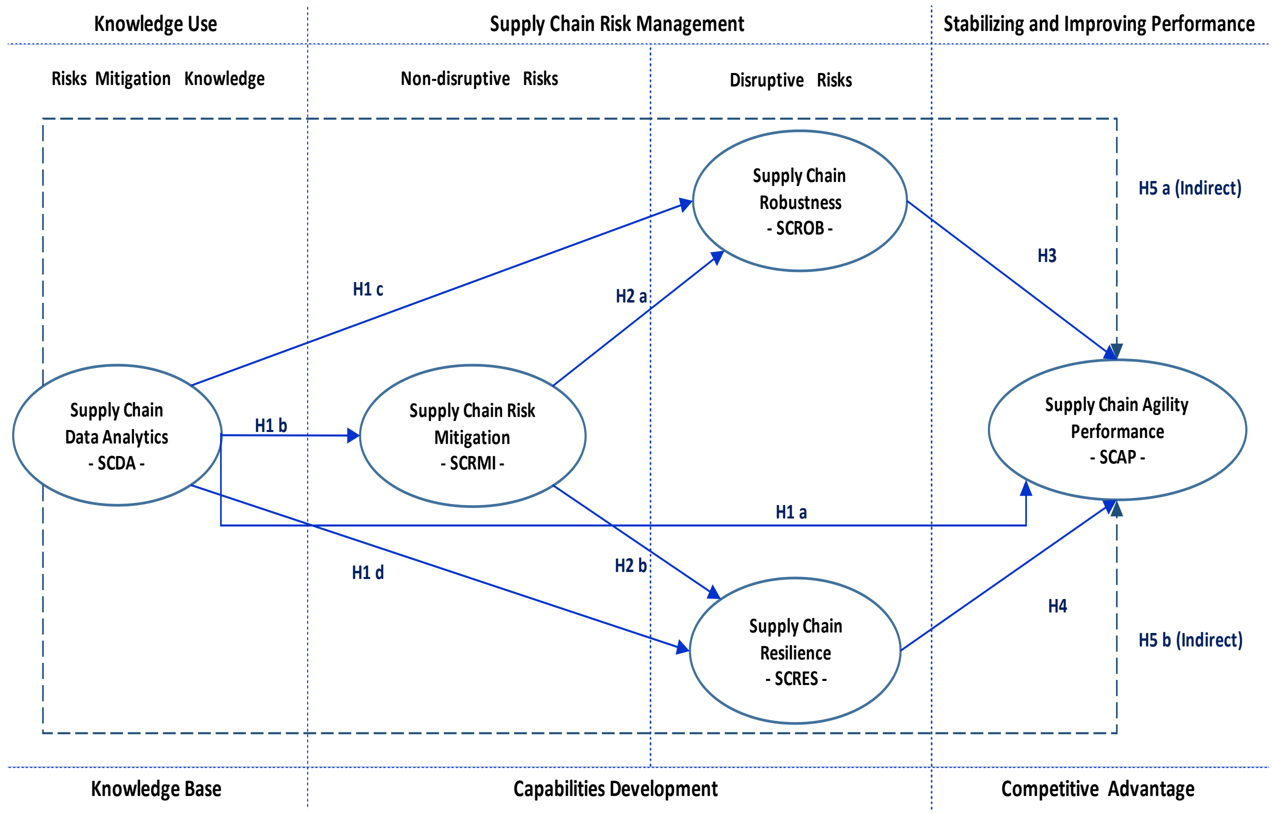

Fig. 1. Research Model

3.1. Direct effects of the SCDA

SCDA and SCAP

One of the main objectives of SCDA is the collection of actionable and new information that can be used to improve operational performance and gain competitive advantage (Khan et al., 2023). In this respect, some authors have distinguished between high-performing and low-performing companies on the basis of SCDA capabilities development (Wamba et al., 2017). Although SCDA capabilities have been recognized as a key competitive factor, their impact on agility performance remains poorly understood in times of disruptions (Khan et al., 2023; Ma & Chang, 2024, Al Mamun et al., 2025).

Therefore, it is hypothesized that: *H1a. SCDA has a positive impact on SCAP.*

SCDA and SCMI

According to Gualandris & Kalchschmidt (2015), companies have been trying to develop strategic and operational capabilities aimed at controlling supply chain risks caused by global events and, consequently, gaining competitive advantage. Recently, companies have relied on the development of SCDA capabilities to strengthen the knowledge base for achieving this competitive advantage (Park & Singh, 2023). Thus, Park & Singh (2023) have shown that SCDA enhances the risk mitigation capability of organizations through early identification and response to risks in the supply chain. Similarly, Modgil et al (2021) have argued that SCDA capabilities enhance sensing and decision-making capabilities within an organization, thereby strengthening SCRMI capability. In addition, SCDA capabilities enable supply chain partners to perform effective environmental analysis and integrate the identification of potential risks and disruptions (Talwar et al., 2021). Therefore, in a disruptive and highly volatile situation, SCDA is intimately linked to SCRMI.

Therefore, it is hypothesized that: *H1b. SCDA has a positive impact on SCRMI.*

SCDA and SCROB

Robustness refers to the capability to withstand various shocks, human errors and variability in the business environment (Wieland & Wallenburg, 2012). This robustness capability plays an important role in times of disruptions because well-equipped, risk-aware supply chains can mitigate or eliminate their occurrence (Kwak et al., 2018). In other words, a robust supply chain is able to withstand, cope with and control disruptions. Robustness capability can save a company time in identifying and implementing the control mechanisms needed to mitigate or, where appropriate, eliminate risks (Kwak et al., 2018). As such, it is important to note that risks identification and mitigation is contingent on the a priori development of SCDA capabilities (Shamout, 2019; Alvarenga et al., 2023).

Therefore, it is hypothesized that: *H1c. SCDA has a positive impact on SCROB.*

SCDA and SCRES

Resilience capability refers to how supply chain partners control disruptions in order to mitigate their impact (Dennehy et al., 2021). Previous studies have highlighted the importance of developing data analytics capabilities for their positive effect on organizational performance (Waller & Fawcett, 2013). However, the literature has not sufficiently examined the role of SCDA capabilities in creating or reconfiguring resilience capability (Dennehy et al., 2021 Recently, Dubey et al. (2021) have argued that SCDA has a direct and positive effect on supply chain resilience. To this end, investment in developing SCDA capabilities leads to improved visibility and, consequently, resilience (Barhmi et al., 2024; Jiang et al., 2025).

Therefore, it is hypothesized that: *H1d. SCDA has a positive impact on SCRES.*

3.2. Direct effects of the SCMI

SCMI and SCROB

Robustness capability plays an important role in mitigating uncontrollable disruptions through the a priori development of SCRMI capability (Kwak et al., 2018). Indeed, robust supply chains are able to withstand, cope with and control disruptions by gaining time to identify and implement the necessary adaptation mechanisms to mitigate disruptions induced by unavoidable risks (Kwak et al., 2018; Shamout, 2019). In view of the above, a robust supply chain remains effective for all future situations (Klibi et al., 2010), preserving the same situation before and after changes without responding to them.

Therefore, it is hypothesized that: *H2a. SCRMI has a positive impact on SCROB.*

SCMI and SCRES

Highly resilient supply chains have a priori a risk mitigation capability enhanced by data analytics. Indeed, resilience enables continuity during severe disruptions caused by uncontrollable events, including Covid-19 and the Russian-Ukrainian war (Yang et al., 2021). Similarly, Jüttner & Maklan (2011) assert that there is an already recognized relationship between resilience and risk mitigation. In addition, Heckmann et al. (2015) have created a theoretical framework for risk mitigation in which supply chain risks are considered a primary state concept, while the resulting disruptions are seen as effects requiring, among other things, resilience capability for their mitigation. Indeed, resilience can be seen as an outcome of the concept of risk mitigation (Pereira et al., 2014). Consequently, the creation or reconfiguration of resilience capability must build on the knowledge already created through data analytics and risk mitigation (Ribeiro & Barbosa-Povoa, 2018; Rashid et al., 2024).

Therefore, it is hypothesized that: *H2b. SCRMI has a positive impact on SCRES.*

3.3. Direct effect of the SCROB and SCRES

SCROB and SCAP

Developing robustness capability as a proactive rather than reactive strategic investment (Wieland & Wallenburg, 2012) enables performance stabilization during volatile phases. Furthermore, a robust supply chain will not experience significant performance degradation in the event of disruptions (Mackay et al., 2020). However, developing robustness capability requires additional financial investment (Wieland & Wallenburg, 2012) induced by the incorporation of redundancies, including multiple suppliers and unused generation or transmission capacity resources. Indeed, robustness is the capability to proactively manage disruptions in the supply chain, thereby stabilizing and improving the agility performance of its partners (Wieland & Wallenburg, 2012). To this end, a robust supply chain is designed to maintain performance at its level during disruptions caused by unavoidable risks. This research argues that SCROB can absorb any SCAP degradation caused by disruptions (Mackay et al., 2020; Liu et al., 2024).

Therefore, it is hypothesized that: *H3. SCROB has a positive impact on SCAP.*

SCRES and SCAP

Resilience has been considered by this research as a capability to ensure supply chain recovery (Munoz & Dunbar, 2015). Furthermore, resilience should be combined with risk mitigation capability (Wieland & Wallenburg, 2013) to cope with disruptive risks constituting a failure of this mitigation capability. Disruptive risks have a serious impact on the entire supply chain, causing disruption to informational, physical and financial flows, and disrupting regular operations (Bahrami & Shokouhyar, 2022). The negative impact of disruptions in the supply chain could be avoided thanks to its resilience capability to return to a favorable performance level within a desirable timeframe after the impact of an incident (Wieland & Wallenburg, 2013). Indeed, this research supports a favorable association between resilience capability and agility performance (Chowdhury & Quaddus, 2017; Altay et al., 2018; Liu & Lee, 2018; Liu et al., 2024).

Therefore, it is hypothesized that: *H4. SCRES has a positive impact on SCAP.*

3.4. Mediating effects of SCROB and SCRES

SCDA, SCROB and SCAP

Data analytics capabilities can boost companies' operational performance (Wang et al., 2016) by providing information and predictive models, which can improve robustness capability dedicated to mitigating disruptive supply chain risks (Shamout, 2021). In addition, accurate and timely data combined with data analytics can generate or reconfigure robustness capability.

Therefore, it is hypothesized that: *H5a. SCROB mediates the link between SCDA and SCAP.*

SCDA, SCRES and SCAP

Recent research has asserted that, in general, information technology innovations (DeGroote & Marx, 2013) and, in particular, data analytics capabilities contribute to improved business performance and supply chain agility (Dubey et al., 2019). As such, Dubey et al. (2021) stated that data analytics capabilities enable companies to gain competitive advantage through resilience capability. Similarly, Bahrami & Shokouhyar (2022) demonstrated that data analytics capabilities support the improvement of business agility performance through the enhancement of resilience capability.

Therefore, it is hypothesized that: *H5b. SCRES mediates the link between SCDA and SCAP.*

4. Research methodology

4.1. Data collection

The study used a survey to collect data from foreign companies operating in Morocco. Through a pilot interview, preliminary data were collected from three manufacturing companies located in industrial acceleration zones to ensure that the questions were understandable to each respondent and without any uncertainty or confusion due to the official language of their respective countries.

Next, the Ministry of Industry and Commerce database was exploited to conduct an online survey in 2024 to test the hypotheses. Indeed, the initial sample included informants involved in the general management and supply chain management of foreign manufacturing companies operating in Morocco. After eliminating mailing errors, the sample contained 845 contacts. At the end of the survey period, 203 completed questionnaires had been received by respondents, representing an acceptable response rate of 24% (Fosnacht et al., 2017). This is because the sample size is medium (Kline, 2023) and the number of observations exceeds the free parameters of the model, which is a necessary condition for identifying a structural model (Kline, 2023). Table 1 presents the profiles of the respondents to this survey.

Table 1. Respondents' Profile Summary

Structure of the sample	Frequency	Valid %
Firm size:		
Less than 100 employees;	50	24.6%
101 to 200 employees;	15	7.4%
201 to 300 employees;	45	22.2%
More than 300 employees.	93	45.8%
Manufacturing industry type:		
Automotive industry;	60	29.6%
Aeronautics and aerospace industry;	53	26.1%
Food industry;	38	18.7%

Structure of the sample	Frequency	Valid %
Pharmaceutical industry;	25	12.3%
Electronic and electrical components industry;	15	7.4%
Rubber and plastic products industry.	12	5.9%
Respondent designation:		
Top management;	95	46.8%
Middle management;	83	40.9%
Lower management.	25	12.3%
Respondent experience:		
Less than 3 years;	18	8.9%
3 to 5 years;	32	15.8%
6 to 9 years;	63	31%
More than 9 years.	90	44.3%
Total	**203**	

4.2. Measurement model

The survey instrument used a seven-point Likert scale (1-strongly disagree and 7- Strongly agree). The measurement items for the theoretical constructs in the research model are adapted from prior studies. This approach allows for the development of formative and composite measures in the context of this study. Therefore, the measurement items can affect the construct with which they are affiliated and which they measure. The measurement items used in this study are presented in Appendix A.

The SCDA capabilities were operationalized by five items adapted from Shafiq et al. (2020) and Khan et al. (2023). The SCRMI capability was operationalized by four items adapted from Yang et al. (2021). The SCROB capability was operationalized by four items adapted from Wieland & Wallenburg (2012) and Kwak et al. (2018). SCRES capability was operationalized by four items adapted from Dubey et al. (2021). SCAP was operationalized by four items adapted from Swafford et al. (2008).

4.3. Nonresponse bias and common method bias

For testing nonresponse bias, the answers of the firms that quickly respond to participate in the survey and enterprises that accept late were compared by means of t-test. There were no statistically significant differences between early and late responses.

To examine the potential threat of variance bias in the common method, a one-factor test was recommended (Podsakoff et al., 2024). The relevant factor analysis revealed that neither a single factor emerged, nor was a general factor identified in the unrotated factor structure. Additionally, in this study, to examine common method bias, the correlation relationships between the constructs were investigated. When the correlation between the concepts is less than 0.90, the bias of the common method is accepted, which is the case for this study.

4.4. Data analysis

Confirmatory factor analysis (CFA) using SPSS Amos 25 was done to validate the factor structure of variables under the focus of this study and assess the validity and reliability of the measurement models corresponding to each construct in the research model (Figure 1). CFA is an appropriate tool because the associations between the proposed items and constructs have been specified. In addition, structural equation modeling (SEM) is useful for examining causal relationships and dealing with multiple dependent variables as well as the error terms of all dependent and independent variables in a structural model (Kline, 2023). Similarly, SEM facilitates the examination of the overall causal fit of a holistic model as well as mediation effects.

4.5. Reliability and validity

The measurement model was evaluated on the basis of the reliability of the internal consistency and the convergent validity of measurements associated with the constructs and the discriminant validity. Internal consistency reliability was tested by Cronbach's α(α> 0.777) and composite reliability (CRs > 0.802), the results of which verified acceptable internal consistency. Convergent validity was assured, as all the loadings were similar to or greater than 0.5, with acceptable average variance extracted (AVE) values (AVEs > 0.510), as displayed in Table 2.

Table 2. Reliability and Convergent Validity Results and Fit Indices

Scale/Item	Cronbach Alpha	CR	Item Loadings	AVE	Fit Indices
Supply Chain Data Analytics Capabilities:					
SCDA1			0.832		
SCDA2	0.892	0.906	0.870	0.670	
SCDA3			0.933		
SCDA4			0.931		
SCDA5			0.501		
Supply Chain Risks Management Capability:					
SCRMI1			0.501		
SCRMI2	0.804	0.835	0.643	0.574	
SCRMI3			0.973		
SCRMI4			0.842		x^2/df (chi-square/ degrees of freedom) = 299.508/177 = 1.692 GFI = 0.843 SRMR = 0.0743 RMSEA = 0.068 CFI = 0.945
Supply Chain Robustness Capability:					
SCROB1			0.889		
SCROB2	0.881	0.891	0.742	0.671	
SCROB3			0.819		
SCROB4			0.839		
Supply Chain Resilience Capability:					
SCRES1			0.737		
SCRES2	0.777	0.802	0.535	0.510	
SCRES3			0.831		
SCRES4			0.744		
Supply Chain Agility Performance:					
SCAP1			0.854		
SCAP2	0.892	0.895	0.875	0.681	
SCAP3			0.831		
SCAP4			0.773		

Notes: CR, construct reliability; AVE, average variance extracted; The goodness of fit index, GFI; Standardized root mean square residual, SRMR; Root mean squared error of approximation, RMSEA and Comparative fit index, CFI.

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In addition, CFA analysis was done to validate the factor structure of variables under the focus of this study. Kline's recommendations (Kline, 2023) on several statistical parameters were used to evaluate the model's goodness of fit (chi-square/degrees of freedom: χ/df < 3, Tucker–Lewis's index: TLI > 0.90, comparative fit index: CFI > 0.90, root mean square error of approximation: RMSEA < 0.10 and standardized root mean square residual: SRMR < 0.09. The hypothesized five-factor measurement model had a satisfactory fit (x^2/df = 299.508/177 = 1.692, GFI = 0.843, SRMR = 0. 0743, RMSEA = 0.068, CFI = 0.945), as displayed in Table 2.

The discriminant validity was verified if the shared variance between the latent variable and its indicators (AVE) was greater than the variances (squared correlation) of each variable with the other latent variables, as displayed in Table 3.

Table 3. Inter-construct correlation estimates and related AVEs

Constructs	SCRES	SCDA	SCRMI	SCROB	SCAP
SCRES	**0.714**				
SCDA	0.549	**0.819**			
SCRMI	0.631	0.412	**0.757**		
SCROB	0.553	0.798	0.239	**0.819**	
SCAP	0.646	0.633	0.445	0.550	**0.826**

Note: Square roots of the AVE are shown on the diagonal.

5. Results and discussion

5.1. Structural model

This study used the R^2 value to estimate the effect of exogenous constructs. The variance is measured by the R^2 that is described in each of the endogenous constructs. So, it measures the model's explanatory power (Hair et al., 2019). Significant, moderate or weak endogenous latent variable R^2 values are 0.75, 0.50 or 0.25 (Hair et al., 2011). Table 4 shows appropriate R^2 values for all dependent variables in the structural model. The R^2 score for the SCAP was 0.54, demonstrating good support for the research model.

Table 4: Results of the path analysis and hypothesis testing

N°	Path			Estimates	P	Support	R^2
H1a	SCDA	→	SCAP	0.172	ns	No	
H1b	SCDA	→	SCRMI	0.257	***	Yes	0.20
H1c	SCDA	→	SCROB	0.518	***	Yes	0.68
H1d	SCDA	→	SCRES	0.300	***	Yes	
H2a	SCRMI	→	SCROB	- 0.116	ns	No	
H2b	SCRMI	→	SCRES	0.605	***	Yes	0.69
H3	SCROB	→	SCAP	0.238	ns	No	
H4	SCRES	→	SCAP	0.382	***	Yes	0.54

Notes: *** p<0.001 and ns: non-significant (p>0.1).

5.2. Hypotheses testing

This study used bootstrapping with 5,000 samples to determine the appropriateness of the path coefficients. Based on the statistical results obtained, with the exception of hypotheses H1a, H2a, and H3 (SCDA ⟶ SCAP, SCRMI ⟶ SCROB, and SCROB ⟶ SCAP), hypotheses H1b (SCDA ⟶ SCRMI), H1c (SCDA ⟶ SCROB), H1d (SCDA ⟶ SCRES), H2b (SCRMI ⟶ SCRES), and H4 (SCRES ⟶ SCAP) were supported. The path coefficients were presented in Table 4 and Figure 2.

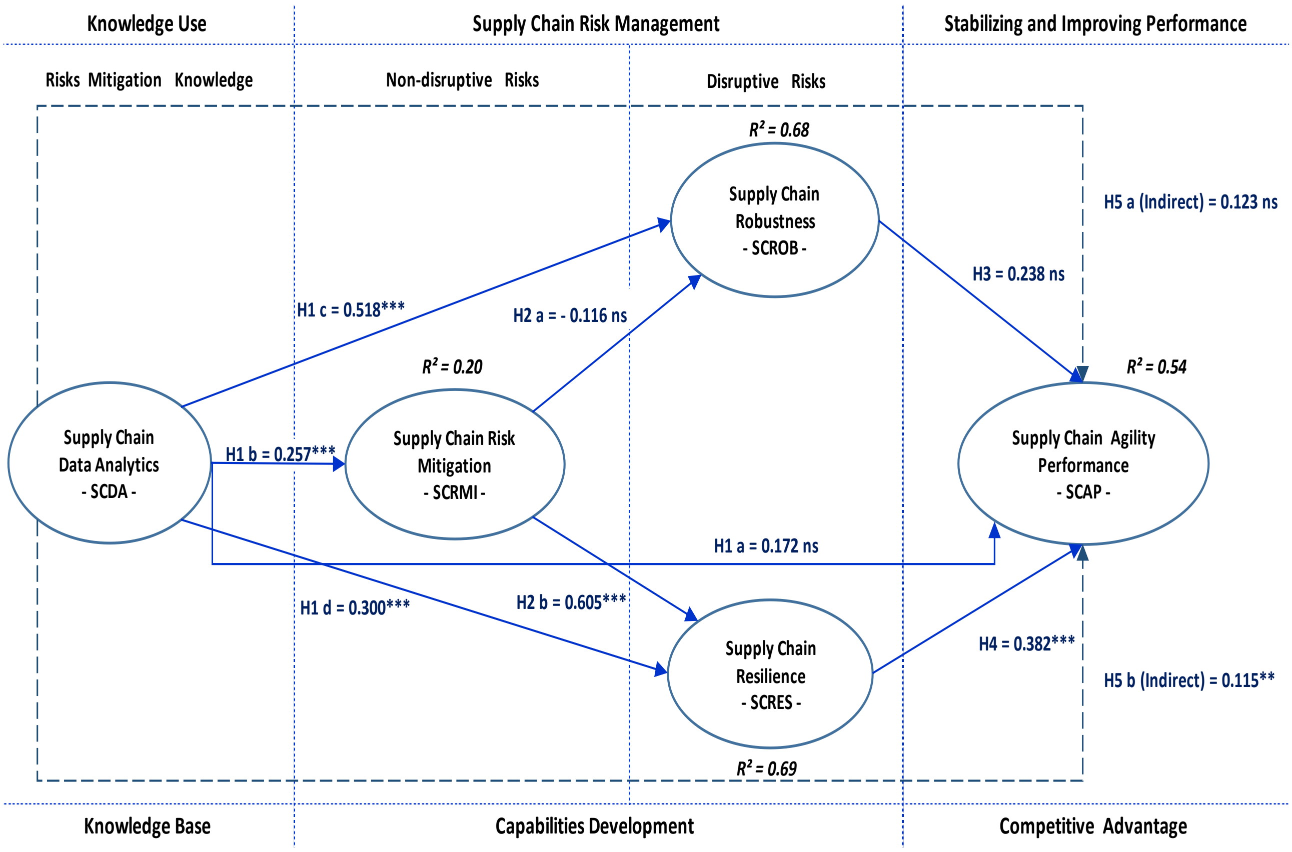

Fig. 2. Research Model Results

5.3. Mediation analysis

This study used the CB-SEM mediation test to assess the magnitude of the mediating effects of SCROB and SCRES capabilities on the relationship between SCDA capabilities and SCPA (Hair et al., 2021). This mediation analysis began by assessing the relevance of indirect effects and then the direct influence of SCDA capabilities on SCPA.

Table 5 summarizes the results of the mediation test using a bootstrapping approach by SPSS Amos 25. The significance of the indirect effects, as shown in Table 5, qualifies the mediation analysis. In addition, this analysis estimated variance accounted for (VAF = indirect effect/direct effect + indirect effect) to test the strength of the mediating effects of SCROB and SCRES.

Table 5. Results of the mediation analysis

Mediated Path	Direct effect with mediator	Indirect effect	VAF	Conclusion	Support
H5a SCDA → SCROB → SCAP	0.415	0.123 ns	0.228	No Mediation	No
H5b SCDA → SCRES → SCAP		0.115**	0.216	Partial Mediation	Yes

Notes: ** p<0.01 and ns: non-significant (p>0.1).

According to Hair et al. (2021), partial mediation is demonstrated when (VAF) exceeds the threshold level of 0.2, and when it exceeds 0.8, full mediation is proposed. The results indicate that SCRES capability partially mediates the association between SCDA capabilities and SCAP, whereas SCROB capability does not mediate this relationship because its indirect effect is insignificant.

5.4. Main findings

By theorizing the phenomenon of SCDA capabilities in the context of manufacturing supply chains, this research work makes important contributions to supply chain management as an emerging discipline (Harland et al., 2006). Because this study focused, among other things, on strengthening capabilities dedicated to risk management through data analytics, it makes an empirical contribution insofar as its results revealed positive effects of SCDA capabilities on risk mitigation (Talwar et al, 2021; Modgil et al., 2021; Park & Singh, 2023), robustness (Wieland & Wallenburg, 2012; Kwak et al., 2018; Shamout, 2019; Alvarenga et al., 2023) and resilience (Waller & Fawcett, 2013; Srinivasan & Swink, 2018; Dennehy et al., 2021).

Furthermore, this study makes a methodological contribution by developing and testing the model in the context of manufacturing supply chains and, therefore, supports calls to go beyond traditional supply chain management (Scholten & Fynes, 2017). That said, this study provides new information on the positive and simultaneous impact of SCDA capabilities on all three risk management capabilities, particularly SCRMI ($\beta = 0.257$, $p < 0.001$), SCROB ($\beta = 0.518$, $p < 0.001$) and SCRES ($\beta = 0.300$, $p < 0.001$), which had not been previously reported.

The main results of this study showed that SCDA capabilities have no direct impact on agility performance. However, their effect is partially mediated by resilience capability (Dubey et al., 2021; Bahrami & Shokouhyar, 2022). In this regard, it is important to point out that, in contrast to previous studies, the results revealed that the effect of SCDA capabilities is not mediated by robustness capability (Wang et al., 2016; Shamout, 2021).

Similarly, SCRMI capability has a positive effect on reactive resilience capability ($\beta = 0.605$, $p < 0.001$), and this is in line with previous studies (Jüttner & Maklan, 2011; Pereira et al., 2014; Heckmann et al., 2015; Ribeiro & Barbosa-Povoa, 2018; Rashid et al., 2024). However, its effect on proactive robustness capability is insignificant, in contrast to previous studies (Klibi et al., 2010; Kwak et al., 2018; Shamout, 2019).

Finally, the results showed that only resilience capability has a positive impact on agility performance ($\beta = 0.382$, $p < 0.001$), in line with previous studies (Chowdhury & Quaddus, 2017; Altay et al., 2018; Liu & Lee, 2018; Liu et al., 2024). However, these results highlighted a non-significant effect of robustness capability on said agility performance, in contrast to previous studies (Wieland & Wallenburg, 2012; Mackay et al., 2020).

5.5. Theoretical and managerial implications

This study sought to understand the mechanisms by which data analytics and risk management capabilities interact to contribute to the stabilization and improvement of agility performance during periods of disruptions in manufacturing supply chains. In addition, data analytics capabilities contribute, through the partial and exclusive mediation of resilience capability, to improved agility performance during periods of supply chain disruptions. This study is one of the first to examine the role of the two capabilities of robustness and resilience in mediating the relationship between data analytics capabilities and agility performance, which should enrich the empirical knowledge of the supply chain management literature.

The results of this study confirm that data analytics capabilities contribute indirectly to improving supply chain performance (Wamba et al., 2020; Khan et al., 2023). As such, this study considers data analytics as knowledge creation and sharing capabilities dedicated to risks and disruptions mitigation, which would facilitate timely and effective decision-making by supply chain managers. Furthermore, the results indicated that only resilience capability serves as a partial mediator between data analytics capabilities and agility performance, providing a valuable framework for investment allocation decisions by supply chain managers. Also, the results of the present study confirm that data analytics capabilities should enable the achievement of competitive advantage in an environment marked by uncertainties and disruptions (Wamba et al., 2017).

Furthermore, the results of this study underlined the vital and exclusive role of resilience capability in maintaining superior supply chain agility in times of risks and disruptions (Christopher & Peck, 2004). That said, managers should be aware that resilience is a prerequisite for success in an unpredictable environment (Gölgeci & Kuivalainen, 2020; Bahrami & Shokouhyar, 2022).

In view of the above, it is important to emphasize that managers must no longer be satisfied with the exclusive use of organizational memory to manage disruptive risks in their respective supply chains, but must resort to the tools and alerts offered by data analytics capabilities to achieve this goal (Singh, N.P. & Singh, S., 2019).

Data analytics reports provide managers with the information and knowledge they need to better understand changes and uncertainties in the environment and, as a result, make more informed and timely decisions in the event of disruptive risks. To this end, the results of this study support the idea that when managers use innovative technologies to improve risk management capabilities, their supply chains would be likely to achieve a higher level of agility performance and, consequently, competitive advantage (Akter et al., 2016; Srinivasan & Swink, 2018).

In a data-driven business environment, investment in big data technology seems a prudent choice for the simple reason that digital transformation is more a strategic than a technological orientation (Rogers, 2016). In this respect, it's important to stress that competitive advantage is a priori determined by the way the technology is exploited, not by the technology itself (Barratt & Oke, 2007).

6. Conclusion

This study was largely motivated by the urgent need to better understand the mechanisms by which data analytics and supply chain management capabilities interact to stabilize and improve agility performance. Although valuable contributions have been made to data analytics, researchers have lagged behind in examining this aspect in manufacturing supply chains. Also, existing studies focus mainly on data analytics as a technology, which has led to limited knowledge of its managerial aspects. To this end, this study uses data analysis and risk management capabilities to advance knowledge on the development of highly agile manufacturing supply chains in times of disruptions. The results showed that resilience is a key capability for building an agile supply chain, unlike robustness capability, whose positive impact on agility performance has not been demonstrated. That said, stakeholders involved in responding to disruptive risks need to take into account the technical and managerial characteristics of data analytics.

Certain limitations can be raised for this study. Firstly, this study did not take into account other dimensions of performance, particularly financial performance, in order to inform supply chain managers about the trade-off between the financial cost of investing in data analytics capabilities and the expected gain in terms of agility performance. Secondly, for reasons of generalizability and simplicity, the data has been consolidated for all companies of different sizes as well as for all manufacturing industries; however, the results could differ depending on company size and industry type. Indeed, the mechanisms by which data analytics capabilities improve risk management capabilities and agility performance deserve to be studied in future, in separate research, for the service sector and the automotive industry, as well as for small and medium-sized enterprises. Thirdly, data analytics capabilities should be explored in relation to artificial intelligence in future research. Finally, the integration of artificial intelligence and other performance dimensions would make the research model more complete for researchers and practitioners alike.

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Appendix A. Construct and survey items

Supply Chain Data Analytics Capabilities (adapted from: Shafiq et al., 2020; Khan et al., 2022):

SCDA1. Collect and analyze the latest unstructured data frequently to improve forecasting and demand planning.

SCDA2. Incorporate analysis of unstructured data into sales and operations planning.

SCDA3. Use advanced statistical techniques to process quantitative (numerical) data from internal and external sources.

SCDA4. Model the entire supply chain (or network) to determine optimal locations for production facilities, distribution centers, cross-docks, etc.

SCDA5. Use simulations to assess non-disruptive and disruptive supply chain risks and/or political, economic or legislative changes.

Supply Chain Risks Management Capability (adapted from: Yang et al., 2021):

SCRMI1. Preventing supply chain risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance).

SCRMI2. Detecting supply chain risks (e.g. internal or supplier monitoring, inspection, tracking).

SCRMI3. Responding to supply chain risks (e.g. backup suppliers, extra capacity, alternative transportation modes).

SCRMI4. Recovering from supply chain risks (e.g. task forces, contingency plans, clear responsibility).

Supply Chain Robustness Capability (adapted from: Wieland and Wallenburg, 2012; Kwak et al., 2018):

SCROB1. Our supply chain and logistics networks can remain effective and sustain even when internal/ external disruptions occur.

SCROB2. Our supply chain and logistics networks can avoid or minimize risks occurrence by anticipating and preparing for them.

SCROB3. Our supply chain and logistics networks can absorb a significant level of negative impacts from recurrent risks.

SCROB4. Our supply chain and logistics networks can have sufficient time to consider most effective reactions.

Supply Chain Resilience Capability (adapted from: Dubey et al., 2021):

SCRES1. Our organization can easily restore material flow.

SCRES2. Our organization would not take long to recover normal operating performance.

SCRES3. The supply chain would quickly recover to its original state.

SCRES4. Our organization can quickly deal with disruptions.

Supply Chain Agility Performance (adapted from: Swafford et al., 2008):

SCAP1. Speed in reducing manufacturing lead-time during periods of supply chain disruptions.

SCAP2. Speed in reducing development cycle time during periods of supply chain disruptions.

SCAP3. Speed in increasing frequencies of new product introductions during periods of supply chain disruptions.

SCAP4. Speed in adjusting delivery capability during periods of supply chain disruptions.

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RESEARCH ARTICLE

Exploring temporal dimensions of benefits realisation management in agile IT environments

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Abstract
This study sheds light on the temporal dimensions of benefits realisation management (BRM) in agile IT project management environments. BRM, focused on aligning strategy with project execution, is inherently temporal, requiring the consideration of past, present, and future outcomes, as well as both short- and long-term benefits. This research examines BRM in agile IT project management through a temporal lens. Adopting a 'time as process' lens, we focus on how actors collectively negotiate, enact, and interconnect the present, past, and future. Through qualitative interviews and a focus group, we examined how agile methods, specifically Scrum and SAFe, interact with BRM processes across different time perspectives. The findings identify challenges such as (1) limited availability of past project data, (2) neglect of long-term benefits, and (3) lack of harmonisation between past, present, and future considerations in benefits realisation. The paper contributes to project management literature by emphasising the importance of temporal leadership in navigating these challenges and improving the harmonisation of past, present, and future actions in BRM.

Keywords
agile; agile project management; benefits realisation management; temporal focus; temporal lens; time as process; temporal work.

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1. Introduction

Time and temporality play a crucial role in strategy and strategic management, yet little is known about how people engage practically with these dimensions in project environments (Bansal et al., 2022). Benefits realisation management (BRM), which is defined as the process of identifying, defining, planning, tracking, and realising organisational benefits (Association for Project Management, 2019), serves as a critical link between strategy and projects (Musawir et al., 2017). Benefits, by definition, are the positive outcomes resulting from a project's deliverables, which are aligned with strategic objectives. Given its emphasis on short- and long-term benefits, BRM inherently involves temporal considerations. However, despite its strategic importance, BRM's relationship with time remains underexplored, particularly in agile IT environments where project timelines and rhythms differ significantly from traditional project management approaches.

Existing literature acknowledges the significance of time in projects and strategy. Time is fundamental to project success: it is a defining characteristic of projects given their limited duration (Burke & Morley, 2016; Lundin & Söderholm, 1995). Agile project management, with its iterative cycles, introduces unique temporal challenges and opportunities. Frameworks like Scrum and Scaled Agile Framework (SAFe) structure project execution around short-term sprints, necessitating continuous adaptation and stakeholder alignment (Khoza & Marnewick, 2021).

A recent review on the theorisation of time in temporary organisations highlights that more research is needed to understand the role of time in the delivery of project success and benefits realisation (Ika et al., 2025). Theorising time is important, but "research on time within an applied discipline needs to ultimately inform, or be informed by, practice" (Bansal et al., 2025, p. 16). Calls have also been made to understand project management in practice (e.g. Clegg et al., 2018; Martinsuo, 2013) and to explore how temporality unfolds in projects (Brunet et al., 2021). This inquiry is especially relevant for the topic of benefits management, as it is gaining increasing attention while its definition and what people really do in practice remain unclear (Aubry et al., 2021). This is what we aim to achieve by exploring what people do to manage benefits in relation to temporality.

In this paper, we adopt a temporal lens, defined as "a conceptual mechanism that assumes time as a central dimension of management, highlights specific management domains in which time matters, and focuses research on the use of time-based concepts that explain how time matters" (Blagoev et al., 2024, p. 2153). We adopt a "time as process" perspective (Blagoev et al., 2024) and define time as an "indivisible flow of interconnected events, an enacted relation between past-present-future" (p. 2158). As such, our interest is in "how actors collectively negotiate, enact, and interconnect the present, past, and future" (p. 2169). The research question guiding this work was: How do stakeholders accomplish agile benefits realisation management through a temporal lens? And more specifically: What are the practices related to temporal dimensions (past-present-future)?

This research contributes to the academic literature by advancing our understanding of BRM through a temporal lens. By illustrating the interconnections between past project learnings, present execution, and future strategic alignment, we highlight how BRM contributes to bridge the gap between temporary and permanent organisations and the critical role of temporal leadership in agile BRM. From a practical perspective, this study provides actionable insights for organisations seeking to improve BRM in agile settings. It identifies three key challenges: (1) limited availability of past project data, (2) neglect of long-term benefits, and (3) lack of harmonisation between past, present, and future considerations in benefits realisation—and offers insights into better harmonising past, present, and future considerations in agile BRM.

The paper is structured as follows: We review the literature on time for projects and strategy, agile methods, and BRM. Then, we present our research strategy by describing our data collection and analysis methods. Our results regarding temporal dimensions in agile BRM in practice are then presented. Finally, we discuss our results by highlighting our theoretical and practical contributions.

2. Background

2.1. Time in projects and strategy

If time is crucial in organisations in general, it is especially so for strategy and projects. The significance of time for strategy is clear given the importance of the future for its realisation. Strategy is also about timing given the need for speedy strategic decisions on firm performance (Baum & Wally, 2003). Finally, time is central to strategic change, although the literature mainly focuses on clock or calendar time (Kunisch et al., 2017).

There have been calls to take time seriously in project management research, and some studies have honoured that call, for example in theorising temporary organisations (Ika et al., 2025) and areas such as project governance (Ika et al., 2024). However, despite the relevance of combining the topics of time and benefits in project management research, very few studies have attempted to do so. The notable exception is Svejvig et al. (2019), who examined acceleration of time to impact within project initiatives aimed at accelerating the realisation of project benefits. This, despite the fact that project success is inherently multifaceted and closely tied to varying time horizons (Varajão et al., 2022).

Time is a broad and multidimensional concept. Its dimensions include tempo, timing, focus/perspective (past-present-future), and rhythm (duration, sequence, transitions, etc.), among others (Adam, 2000). Based on an extensive review of time in strategic change (Kunisch et al., 2017), three dimensions have been identified as particularly relevant to this topic: urgency, temporal focus, and temporal depth. Firstly, urgency can be a characteristic of events or of individuals concerned with the passage of time and feeling generally hurried across situations (Shipp & Cole, 2015). Secondly, temporal focus refers to the extent to which individuals, groups, and organisations direct their attention to the past, present, and/or future, and as such, it is concerned with the direction(s) of temporal attention (Kunisch et al., 2017). This concept is very similar to that of time perspective, defined as "patterns of focusing on the past, present, and future" (Waller et al., 2020, p. 263). Finally, temporal depth is defined as "the temporal distances into the past and future that individuals and collectivities typically consider when contemplating events that have happened, may have happened, or may happen" (Bluedorn & Waller, 2006, p. 366). This concept is very similar to time horizon, defined as the "temporal distance into the future (e.g., short-term versus long-term)" (Chen et al., 2021, p. 3). Temporal depth, concerned with the length of the horizon (Kunisch et al., 2017), is considered as a dimension that varies greatly between individuals and even whole societies (Bluedorn & Ferris, 2004). Short and long term can be considered as a way to measure temporal depth. Figure 1 illustrates these two concepts and how they are related to time.

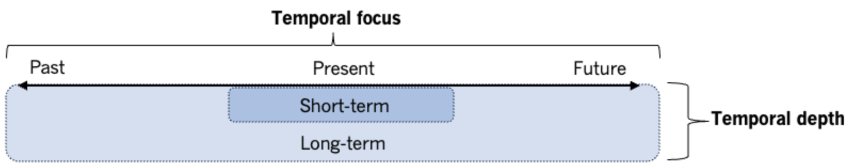

Fig. 1. Temporal dimensions

Time is key for project organising in several ways. As evoked by Söderlund (2013), we operate in times in which "the need for speed, the difficulties of timing, the challenges of synchronizing cross-functional teams, and the development of absorptive capacity as a dynamic phenomenon" (p. 125) are key topics for practitioners. As such, he proposes a research agenda that pays more attention to temporal concepts (as timing and temporary relationships).

Time and temporality, and their relevant dimensions for strategy and projects, are manifold. In the next sections, we will delve more specifically into the topic of benefits and success, and then agile methods and BRM in this context.

2.2. Agile methods

While the use of agile methods has increased in recent years, a deeper understanding of their practical implementation and broader implications for project management is still needed (Xia et al., 2024).

Agile methods are iterative approaches to delivering artefacts—primarily IT and digital deliverables—that enable adaptive strategy execution by incorporating continuous customer feedback and insights from previous iterations, ensuring ongoing improvement before the final project's completion. Formulated as an alternative to traditional methods (i.e. waterfall) and based on the agile principles, agile projects are performed by a small collaborative work team, generally fewer than 15 people (Kruchten, 2011) or even less (e.g. maximum 9 people in the Scrum framework). Scrum is an agile framework that emphasises iterative development, team collaboration, and adaptability, using time-boxed sprints to deliver incremental value (Vallon et al., 2018). Teams can respond quickly to change because they develop artefacts incrementally, in short time-boxed development cycles or "sprints", and they focus on developing the highest priority features in one to six-week delivery increments (Hobbs & Petit, 2017).

Organisations begin to transfer agile principles and approaches to large levels for distributed teams, large projects, and critical systems (Hobbs & Petit, 2017) in order to reap the benefits of agile methods at organisational level. These advantages can be summarised as increased collaboration, improved alignment with business needs and a better work environment, among others (Digital.ai, 2023). Various scaling agile frameworks do exist. SAFe is the most widespread and expands agile principles to enterprise-level organisations, allowing multiple teams to work together on large-scale projects through a structured approach that combines lean, agile, and DevOps practices (Remta & Buchalcevova, 2021).

2.3. Benefits realisation management

Benefits, in the context of project management, refer to the positive outcomes derived from a project's deliverables, aligned with an organisation's strategic objectives. These benefits can be classified as either tangible or intangible. Tangible benefits are measurable and can be assessed using key performance indicators (KPIs) such as return on investment (ROI), cost savings, customer satisfaction, operational efficiency, and stakeholder value (Ward & Daniel, 2012). Intangible benefits, on the other hand, are more subjective and often depend on stakeholders' perceptions, making them harder to quantify (Breese et al., 2015). The relationship between benefits and project or product success operates on different time scales. At project level, benefits contribute to success by ensuring that objectives are met within the defined scope, schedule, and budget. However, true value realisation often extends beyond project completion, as benefits linked to the project determine whether the delivered outcomes generate long-term value for stakeholders (Martinsuo, 2020). This distinction highlights the importance of BRM in bridging short-term project success with long-term product and business success.

BRM encompasses the entire process of identifying, defining, planning, and ultimately realising these benefits, from their initial inclusion in the business case to their actualisation at the project's conclusion. Various authors present their own BRM processes (Ashurst, 2011; Bradley, 2016; Project Management Institute, 2019; Ward & Daniel, 2012). According to the Association for Project Management (APM, 2019), BRM consists of three key steps: 1) benefit definition involves identifying and articulating the expected benefits of a project, ensures alignment with strategic objectives, and provides a foundation for decision-making; 2) benefit planning defines how benefits will be realised, specifying necessary actions, responsibilities, and measurement criteria; and 3) benefit measurement focuses on tracking, evaluating, and ensuring that the planned benefits are actually achieved, often requiring post-project reviews and data analysis. These BRM processes follow a more traditional waterfall project management approach and are thus not necessarily appropriate for an agile environment where an iterative approach is followed.

Many organisations integrate benefits definition and planning into their project selection and strategic decision-making processes, as these steps help justify project investments (Aubry et al., 2021). However, research suggests that benefits management practices are often superficial, with benefits being framed primarily as a persuasive tool rather than a rigorous management discipline (Aubry et al., 2021). Furthermore, benefits measurement presents challenges due to limited data availability, uncertainty, and the complexity of attributing benefits directly to a single project (Breese et al., 2015).

Marnewick and Marnewick (2022) identify an agile BRM process that operates across three levels. At portfolio level, organisational strategy is translated into value streams, ensuring alignment with business objectives. The planning and prioritisation level focuses on identifying, planning, transitioning, and sustaining benefits. Here, past benefits realisation performance informs current decisions on project adjustments, with a forward-looking approach aimed at maximising long-term benefits. Re-evaluation and reprioritisation occur frequently, often within programme increment (PI) cycles. The implementation level is where agile activities, typically governed by Scrum, take place. At this stage, decisions focus primarily on creating artefacts that meet product owner requirements, rather than directly addressing benefits realisation. However, past performance in artefact creation influences present decisions and the organisation of future work. These decisions tend to be short term, shaped by iterative cycles rather than long-term strategic benefits.

This brief introduction to the topic foreshadows the richness of the temporal dimensions related to BRM, and even more so in an agile IT context, which will be explored in this paper. In order to shed light on this matter, we will now present our methods.

3. Methods

To answer our research question (how do stakeholders accomplish agile BRM through a temporal lens?), two sets of data were analysed. The first phase involved individual interviews with people whose organisations had implemented scaled agile in their IT environment in South Africa. The second phase was a focus group in Canada involving four participants. These participants were involved in agile IT projects and their organisations were in the process of scaling agile. A decision was made to start with interviews to gather information on agile benefits realisation due to the topic's exploratory nature (Yin, 2018). The focus group allowed participants from different organisations to discuss BRM processes and compare this with what was identified in the first phase. Three participants came from two large financial organisations, and one was a consultant with a great deal of experience in various organisations and working in a para-public organisation at the time of the focus group.

The interview guide of phase 1 consisted of four sections; one section that focused on value and benefits realisation within a scaled agile environment applies to this article. The focus of this section was to determine whether an agile benefits realisation process exists or not and what the associated challenges were. The interviews were conducted virtually by two researchers via Microsoft Teams and recorded for analysis purposes. As shown in Table 1, nine interviews ranging between 33 minutes and 1½ hours were conducted. Purposive sampling is a non-probability sampling technique where the two South African researchers deliberately selected the participants based on their specific involvement in the scaled agile journey. Purposive sampling is useful when studying specialised populations, ensuring that participants have the necessary experience or knowledge to provide meaningful data. To reduce the inherent bias of purposive sampling, the Canadian focus group was used to verify the results of the South African participants and no differences emerged in the data from the two different countries. Despite differences in geographic location, both South African and Canadian participants worked in large-scale IT projects using SAFe, which likely contributed to the consistency of their responses.

The focus group involved four Canadian participants and took 1½ hours (see Table 2). These participants were also identified using purposive sampling due to their involvement in the scaled agile journey of their respective organisations. This session was chaired by one of the South African researchers to ensure consistency. The focus was also on how benefits are realised in an agile environment.

Table 1. Summary of interviewees

Type	Role	Identifier	Agile framework implemented	Agile experience (years)	Duration of interview
Financial institution (1)	Head of PMO	PMO-1	SAFe	11	00:53:30
	Head of Transformation	TRAN-1	SAFe	8	00:45:38
Consulting	Partner	PART-1	SAFe	11	01:23:49
Financial institution (2)	Business IT executive	IT-1	SAFe	10	00:57:45
Entertainment company	Change manager Business transformation Consultant	CHANGE-1 TRAN-2 CONS-1	SAFe	2 2 10	01:03:29
Financial institution (3)	Chief value officer	CVO-1	SAFe	7	00:39:18
IT outsourcing	Agile coach	COACH-1	SAFe	10	00:33:06

Table 2. Summary of focus group participants

Type	Role	Identifier	Agile framework implemented	Agile experience (years)
Financial institution (4)	Engineer train release	ETR-1	SAFe	5
	Scrum of scrum masters	SCRUM-1	SAFe	5
Consulting	Partner	PART-2	SAFe	15
Financial institution (5)	Portfolio manager	Port-1	SAFe	8

The transcriptions went through an iterative process of open coding which summarised the data into smaller meaningful units called codes and themes (Saldaña, 2021; Williams & Moser, 2019). ATLAS.ti was used to facilitate the coding process. Coding related to the temporality of benefits realisation, and was done by one of the authors and verified by the other two authors. The first round of coding ensured consistency in identifying themes, and the other two authors verified the results to enhance reliability, reduce bias, and ensure the accuracy of interpretations. During the first round, 85 quotations were coded across four themes (benefits identification, benefits planning, benefits tracking, and benefits harvesting); this resembles the agile benefits realisation process. During the second round of coding, three general themes (past, present, and future) were identified as per the research topic and were then refined through specific topics related to each perspective (e.g. retrospectives and reviews for past focus). The importance of temporality in the agile BRM process emerged from the data and the analysis was iterative since the data were considered with these new dimensions in mind. This resonates with the seminal work of Kaplan and Orkowski (2013) on temporal work in strategy-making. The focus while collecting data was not on time per se, but the authors found that temporality was crucial and led them to propose this concept. We will come back to this in the discussion, but first we delve into our results.

4. Results

Our results address the following research question: How do stakeholders accomplish agile BRM through a temporal lens? Based on interviews and the focus group, we present elements from our empirical investigation as they are related to the past, present, and future.

4.1. The past

Participants evoked the past through reviews, retrospectives (done either at project or organisational level), and data on past projects. Regarding this last point, the issue of the limited amount of data on past projects was mentioned. Despite holding retrospectives, benefits were seldom measured on past projects. The focus was rather on the present (actual projects) or the future. The lack of attention on the past is clear in the following quotation:

> They don't look back to the past. They did their postmortem, their retro action, and they have everything that they want to have, and they go to the next thing. So for the long-term, looking at the benefits, it's not in the scrum or the DevOps team that they're gonna do it. [Group Discussion]

The retrospectives were used by organisations to reflect on whether the product would still achieve the intended benefits. The focus was looking at what was wrong in the past with a view to the future.

> We do quite a number of these retrospectives where we look at what went wrong. Afterwards, in terms of how the benefits were not realized and all sorts of issues with the software. Delivery hasn't happened. Now you go and you look at what went wrong. The what goes wrong often goes with strategic alignment. [PART-1].

The retrospectives were also used for alignment purposes, as stated by IT-1: "*So there's retrospectives. You kind of have the different levers to pull it, so to say if they represented on after production support, then next increments. Let's figure out how we do make slightly more, or let's make sure we get a chunk of that capacity available to invest*." However, as we can see, the past is closely related to the future, as this participant projected himself into the future based on what had been assessed during the retrospective.

Reviews are an important aspect of agile, as stated in its principles (Agile Manifesto). These reviews are also incorporated into scaled agile. "*We actually sit every month with our retail executive and he's managing his eggs where we review the programming increment execution*" [IT-1]. COACH-1 felt that in order for reviews to be meaningful, "*the metrics and the process of setting that up is done from the onset*". Participants mentioned that for reviews to be successful, they must be done frequently to address issues of the past but must also be reviewed against predefined metrics. Here, the dimension of rhythm is also factored in as the frequency is deemed important.

4.2. The present

The present is evoked through the act of aligning all the visions and the product roadmap, in an ongoing effort, and the idea of going in the same direction. This also refers to rhythm and the sense of progression. Monitoring and reporting on the progress of initiatives is also done with a focus on the present. Participants mentioned data on what was happening in ongoing projects, which seemed to be more readily available and actionable than data on past projects.

Although alignment was focused on the present, it was done based on actions in the past and with an eye on the future. To illustrate this, CVO-1 mentioned that "*I think we sensed we were spending an enormous amount of money on change the bank with very little tangible work to show for it and what we've now done is focused more on the alignment of our change the bank works to the achievement of the outcomes aligned to our true north metrics*." Alignment was a challenge. "*Because today I think one of the most complicated things is that our roadmaps are not always aligned between all departments. We are working on this, and you will be using our product there and, you will deliver this here*." [Group Discussion]. This challenge might have a negative impact on the future if alignment is not achieved between different projects within an organisation.

Participants felt there was a need to ensure that everyone was pulling in the right direction. As with alignment, direction is based on the past. "*I think to me it's about aligning all the visions and roadmaps and going into the same direction*" [Group Discussion]. To facilitate direction, team members need to be close to each other and communicate regularly. "*At some point we managed to co-locate, you know, business product owners with teams and they could then be right there* *every day and see what the teams are doing and get feedback, give direction. So I think that created a lot more visibility of how we're actually progressing*." [IT-1].

The purpose of monitoring is to understand the current situation around all the projects and whether they will achieve the intended benefits. "*So those [the benefits] are definitely being monitored. When we say benefits realisation, so ideally what you'd like to see and to come to your question, then you know every project, every initiative that we run*." [PMO1]. Again, this monitoring, done in a given time (present) is connected to both the past (metrics that have been defined) and the future (corrections deemed necessary to adjust).

4.3. The future

Finally, the future is evoked through the act of planning and the artefacts of vision and roadmap of all projects. It is also evoked through the presence of short- and long-term benefits. As seen in the next quotation, short-term benefits were related to the initial delivery (minimum viable product or MVP), and long-term benefits to the final product.

> That minimum viable product you are already harvesting some benefits from that MVP or, someone else and you mentioned earlier that the MVPs are only staggering and only afterwards you start getting the benefits and you only get benefits that like maybe 30% up front and only the long-term benefits so that they say is almost immediate benefit short-term benefits based on the MVP and then long-term benefits if the whole product is released. [IT-1]

The concept of minimum viable product (MVP) is specific to the agile context and corresponds to an earlier version of a product that aims to gather knowledge to improve the product further. The shortest temporal depth (short term) of BRM could therefore be a distinction from more traditional approaches, where the benefits will be harvested later on, when the final product is delivered.

The focus of planning is, of course, in the future. But since the future is unpredictable, planning is also subject to change. "*So what we find in our model is what you'll find in our three-year planning, you've got now benefits and things are linked to it and people have baked into the business case. But when you respond to change within agile environment, things move*." [IT-1]. The importance of planning lies in linking the anticipated future benefits to the strategy and vice versa. "*Because in the PI planning, you start to link all those objectives to strategy and benefits.*" [TRAN-1]. In conclusion, "*the whole benefits process is about identifying the benefits, planning prioritization around it, and then the delivery of it, and then the long-term sustainment of those benefits*." [Group Discussion].

Other issues related to BRM have to do with planning:

> So if you then look at business benefits, and I mean you must reliably be able to predict the costs involved or the cash flows. Plus then the outcome. And when you build for yourself, it's probably more difficult to predict those, but in saying that when you go into a process where you acquire, the blind spot is often that you need to change the organization to fit what you buy. Your culture can't stay the same, so there are a lot of these qualitative trade-offs that are not account for in [benefits realisation management]. [PART-1]

Here, the difficulty to grasp or connect in some way with the future was deemed problematic.

In a scaled agile environment, the roadmap is scheduled for deliverables looking at a planned horizon. It creates a linkage between the vision and operations. "*So, this group of people are owning the vision of what we are doing and the long-term, like three years roadmap, of all our products*." [Group Discussion]. In the roadmap lies the long term; hence a deeper temporal depth (in the future).

The vision and strategies are future focused. IT-1 mentioned that they were "*really making sure that we actually harvest benefits out of that, and I think in terms of the purpose of the organization and where we want to go and driving our strategy was important for us to make sure we can only kind of sign up for the right kind of initiatives*". This was supported by CHANGE-1 with the focus of the product alignment to deliver on the strategy. "*I want to [realise] certain products, but it would be going further to say OK, how does that actually deliver on my objectives for the business unit? So that's where that link to strategy comes up and then the levers and actions would be what we would do to actually deliver that?*" [CHANGE-1]

4.4. The interrelationship nature of temporal focus for benefits realisation management

Although the concepts presented may be related to a different temporal focus, either one of the past, present or future, a key element that emerged from the data is the interrelated nature, as participants frequently referenced many temporal elements at the same time. In the following example, strategic alignment is closely related to retrospective (past) and checking if the benefits have been realised:

> You see, I've put it first because when we actually conduct a retrospective, that's where we can really identify key issues. We do quite a number of these retrospectives to examine what went wrong. Later, when benefits haven't been realized and there are various issues with the software—such as failed delivery—we go back and analyze what went wrong. More often than not, these issues are tied to strategic alignment. So, if I think about ultimately realizing my benefits, ensuring strategic alignment must be the first priority. [PART-1]

Past, present, and future actions can be integrated effectively by continuously assessing the present, reflecting on the past, and planning for the future. This relationship, for instance, is observed during retrospectives or the ceremonies related to inspect and adapt processes. Effective BRM requires a structured approach that integrates past project learnings, real-time execution, and long-term planning. Our findings indicate that when organisations fail to systematically connect these temporal dimensions, BRM efforts become fragmented.

4.5. Benefits realisation management and temporal challenges

Three key challenges related to time and benefits were uncovered. The first is the limited data available on past projects and benefits. People seem to be prone to move forward, but benefits on past projects are not always well measured and followed up. The second challenge has to do with long-term alignment and long-term benefits realisation. In some cases, agile seems to bring a slight focus on the present, resulting in a neglect of the long term. As mentioned by this participant: "*What about those long-term benefits? Two years, three years from now? Do you actually care about it or not? Do you hope that it will happen eventually?"* The lack of continuity regarding the people in charge of benefits was mentioned as an element contributing to this issue. Finally, a third and more global challenge is the lack of harmonisation between the past, present, and future, as evoked in this quotation: *"I would say the biggest challenge is a lack of harmonised process"* [Group Discussion]. The following figure illustrates these key temporal challenges in relation to temporal dimensions.

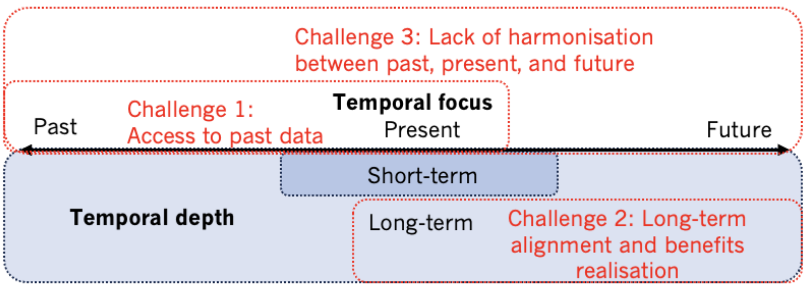

Fig. 2. Key challenges related to temporal dimensions

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5. Discussion

This study offers three key contributions, each of which is detailed in the following sections.

5.1. Advancing the theoretical understanding of time in benefits realisation management

Temporal focus (the degree to which individuals attend to the past, present, and future) influences how people "incorporate perceptions about past experiences, current situations, and future expectations into their attitudes, cognitions, and behavior" (Shipp et al., 2009, p. 1). It has been identified as a critical predictor for strategic outcomes (Back et al., 2020). High levels of past and future focus by CEOs have been recognised as helping to promote strategic change, especially in highly dynamic environments, and a predominance of either focus negatively affecting its implementation (Back et al., 2020). In a similar way, our paper highlights that a lack of focus on the past (lack of past data) or future (not thinking enough about the long term) have both been identified as issues. Temporal focus is often studied in isolation and very little research has examined how they are related (Kaplan & Orlikowski, 2013; Slawinski & Bansal, 2017).

Temporal work is closely related to the relationship between past, present, and future (what represents temporal focus). Kaplan and Orlikowski (2013) have proposed the concept of temporal work in strategy-making to depict how actors resolve differences and link their interpretations of the past, present, and future in order to construct a strategic account enabling concrete strategic choice and action. Temporal work can be defined as "any individual, collective, or organizational effort to influence, sustain or redirect the temporal assumptions and patterns that shape strategic action" (Bansal et al., 2022, p. 7). It has also been used to study more specifically how individuals influence temporal structures as the ones at the interface between temporary and permanent organisations (Geraldi et al., 2020).

Since BRM is about aligning the vision of the past, present, and future, we argue that it represents an illustrative example of temporal work in action. In this paper, we explore which facets of BRM are related to the past, present, future, as well as temporal depth (short and long term). We highlight that actions linking the past, present, and future are key for BRM, and we underline the lack of harmonisation as a key issue, along with the neglect of the long term and the limited data available on past projects and benefits. Monitoring is a specific example highlighting the importance of integrating the past, present, and future, since it is done in a given time (present) and must be connected to both the past (metrics that have been defined) and the future (corrections deemed necessary to adjust). The lack of connection to the past or future would be detrimental, as monitoring cannot be done in temporal isolation and must be related to what has been defined as the objectives (past) and bring changes (to the future) to allow improvements. The retrospective is another specific example of the value of integrating different focus points. Looking only at what was wrong (in the past) without aiming to improve (in the future) would be a useless exercise. Figure 3 illustrates the relationships between the dimensions of temporal focus and depth, as well as rhythm, which has been mentioned as a key element.

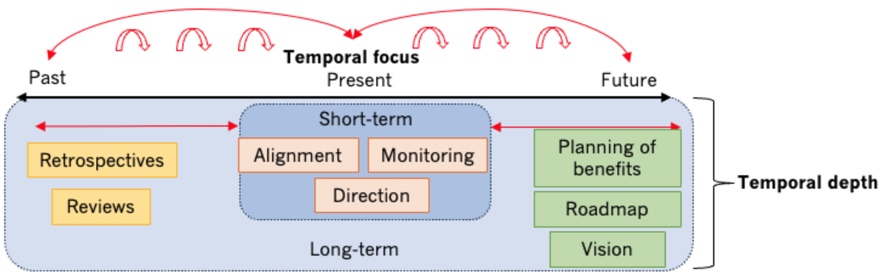

Fig. 3. Relationships between dimensions and rhythm

5.2. Bridging the gap between temporary and permanent organisations through BRM

Research indicates that benefits management practices are often lacking in depth, with benefits frequently presented as a persuasive mechanism rather than being treated as a structured and rigorous management discipline (Aubry et al., 2021). The realisation of value often continues beyond project completion, as the benefits associated with the product ultimately determine whether the delivered outcomes create lasting value for stakeholders (Martinsuo, 2020). This distinction underscores the critical role of benefits management in linking short-term project achievements with long-term product impact and overall business success.

The co-creation of value requires the management of tensions at the temporary-permanent boundary (Kier et al., 2023). We contribute to the notion of moving beyond the traditional view of permanent and temporary organisations as merely opposing structures (Goetz & Wald, 2022) by proposing that BRM serves as a bridge between the two. Through its focus on the future, BRM establishes a crucial link between projects and their long-term impact on the organisation. Our work highlights an area where projects are not seen simply as time-bound endeavours but as contributors to an ongoing cycle of value creation. Rather than ending with project completion, BRM builds on past achievements and ensures that the value generated continues to shape the organisation's future.

The view of projects as time bound has been recognised as limited, particularly in cases such as serial or never-ending projects, as well as those deeply embedded in ongoing interorganisational partnerships (Sydow & Braun, 2018). Agile IT projects provide another example that illustrates this perspective. The iterative nature of agile enables a shift away from a linear view of the project. The importance of frequency and continuous updates has been highlighted in the results, illustrating these aspects related to rhythm. As such, this topic contributes to expanding our view of projects and, more specifically, how we understand them from a temporal point of view. This is in line with other studies (e.g. Brookes et al., 2017; Stjerne & Svejenova, 2016; Whyte & Nussbaum, 2020) that have started in recent years to highlight continuity, transitions, long-term, and multiple temporalities of projects in relation to permanent organisations – two entities that are seen as less and less distinct one from each other. However, the absence of a clear project end point may pose challenges to evaluating project success as it is typically conceived (Varajão et al., 2022), hence calling for a deeper examination of how such non-linear and ongoing temporalities affect practices and conceptualizations of project work, success, and value creation.

5.3. Introducing temporal leadership as a key capability for agile BRM

Ancona et al. (2001) coined the term 'temporal leadership' as a way for senior teams to operate simultaneously in the present and the future.

> Teams enact temporal leadership as they entrain their organizations to technology and competitive cycles, manage across multiple time frames, and create temporal architectures for their organizations (p. 656).

Temporal leadership determines whether time pressure enhances performance or hinders it (Maruping et al., 2015). It has been applied to team level and defined as "leader behaviors that aid in structuring, coordinating, and managing the pacing of task accomplishment in a team", such as "scheduling (e.g., reminding team members of deadlines, setting interim milestones), synchronizing (e.g., coordinating the team so that work is finished on time), and allocating temporal resources (e.g., building in time for contingencies and problems)" (Mohammed & Nadkarni, 2011, p. 492).

Even though it has been studied in project teams or high-level management (Waller et al., 2020), we know less about continuous agile IT teams as our context. Given the nature of BRM and the necessary articulation of the past, present, and future, we propose the concept of temporal leadership as a key capability for agile BRM.

In an agile environment, teams can leverage temporal leadership to manage value creation effectively throughout project iterations. The existing definition of temporal leadership focuses primarily on the present and future; however, we propose an expansion of this definition to also encompass the past. This is particularly relevant, as two of the three key challenges identified in our study are directly linked to the past—either through the lack of historical data or the difficulty of integrating past, present, and future considerations in BRM.

Furthermore, since the responsibility for BRM is often unclear, an important area for future research is shared temporal leadership—examining who can contribute to integrating the past, present, and future in BRM processes, and how. This is particularly relevant in agile environments, where autonomy plays a central role. In such contexts, teams themselves could assume part of this responsibility, actively shaping the temporal alignment of benefits realisation.

6. Conclusion

This study explored the temporal dimensions of benefits realisation management (BRM) in agile IT project environments. By adopting a temporal lens, we provide insights into how stakeholders navigate past, present, and future considerations in benefits realisation. Our research identifies three critical challenges in agile BRM: 1) limited availability of past project data, which hinders learning from previous initiatives and impairs future decision-making, 2) neglect of long-term benefits, as agile environments tend to prioritise immediate outcomes over sustained strategic value, and 3) lack of harmonisation between past, present, and future considerations.

Benefits management continues to attract growing interest, both in practice and in academic literature, while we know little about its actual practice (Aubry et al., 2021). This study aimed to contribute to "opening the black box of benefits management in the context of projects" (Aubry et al., 2021, p. 434). It does so by uncovering an important dimension for project studies, which is temporality, through investigating how people accomplish agile BRM through a temporal lens.

Temporary organisations have been characterised as evolving in a bubble "decoupled from other past, contemporary, or even future sequence of activities" (Lundin & Söderholm, 1995, p. 446). By illustrating temporal work, we uncover other dimensions of time in addition to the objective one that dominates project management rationale (Delisle, 2019; Söderlund, 2013).

The paper makes three key theoretical contributions. Firstly, it shows how BRM is about aligning the vision of the past, present, and future and, as such, how it represents an illustrative example of temporal work. Secondly, it illustrates how BRM is an area connecting both temporary and permanent organisations, contributing to a vision of projects that are not finite and decoupled from their organisations. Thirdly, it introduces the concept of temporal leadership as a key capability for BRM.

Unlike prior studies that focused primarily on benefits realisation within structured governance models (Ward & Daniel, 2012), our study reveals that the temporal dimension is an underexplored yet critical factor in BRM. We extend the literature by demonstrating how agile's iterative nature introduces a distinct challenge: organisations often optimise for short-term benefits at the expense of long-term value realisation. This finding contrasts with traditional project management environments, where benefits realisation is often more linear and structured (Project Management Institute, 2019). Our findings expand the current understanding of BRM by emphasising the importance of temporal alignment—ensuring that past learnings, present execution, and future planning are integrated.

This article also has practical contributions, since it highlights three challenges that people face while managing benefits in an agile context and consequently areas for improvement are suggested, such as better access to past data, a long-term alignment, and harmonisation between the past, present, and future.

This is an emergent work building on a relatively small amount of data, from a limited number of organisations. This raises issues of validity, and the work is not meant to be generalisable to other industries. However, we see pursuing this inquiry and collecting more data to enrich the understanding of these topics as a potential research avenue. Concerning reliability, the methodology relies on interviews and a focus group, which inherently involve subjective interpretations from participants. Differences in individual perspectives, organisational cultures, and maturity levels of agile adoption may influence how temporal aspects of BRM are perceived and enacted.

A longitudinal research design would be useful to gain a more nuanced understanding of temporality in BRM. An example of a temporal dimension that has not been investigated here is urgency, defined as a characteristic of events or of individuals concerned with the passage of time and feeling generally hurried across situations (Shipp & Cole, 2015), and one of the three key temporal dimensions relevant for the topic of strategic change (Kunisch et al., 2017). For example, how does urgency influence BRM in its different processes (identification, planning, execution, and sustainment) and through the different levels (strategy, planning and prioritisation, and implementation)?

Finally, benefits measurement represents a relevant topic that could be further explored through the lens of temporal dimensions. A quantitative approach could provide deeper insights into how benefits evolve over time, assessing the long-term impact of agile projects, and identifying patterns in benefits realisation across different time horizons. Future studies could also examine the relationship between short-term iterative gains and sustained strategic value, offering empirical validation for the temporal dynamics of BRM.

This study was conducted in an agile context, but comparing both traditional and agile project environments would provide valuable insights. One potential avenue for future research is examining whether the emphasis on the present that we identified is inherently linked to the fast-paced nature of agile methodologies. The short-term perspective—such as the benefits derived from a minimum viable product—may be a defining characteristic of agile settings. Therefore, it would be beneficial to compare temporal depth in agile versus traditional project management approaches and analyse its impact in each context. Additionally, while this study highlights the importance of temporal focus in BRM, further research with a dedicated research design is needed to explore this aspect in greater depth.

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RESEARCH ARTICLE

Unveiling the potential of metaverse in project management education

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Abstract
The Fourth Industrial Revolution (4IR), driven by technological advancements such as Artificial Intelligence (AI), has transformed industries, reshaping the skills required in the workforce. Project management education must adapt to these changes by integrating innovative teaching methods to prepare future professionals. This study explores the potential of the metaverse, an immersive virtual environment, to revolutionize project management education. By offering interactive, real-time simulations and personalized learning experiences, the metaverse enables learners to engage with complex project management scenarios beyond the limitations of traditional classrooms. This research combines a literature review and qualitative analysis of project managers' perspectives to assess the benefits and challenges of incorporating the metaverse into educational curricula. The findings highlight the potential for enhanced engagement and the barriers to adoption, including technology access and learning curve concerns. The study concludes by proposing future research directions and addressing limitations regarding the scalability and effectiveness of metaverse-driven education in diverse project management contexts.

Keywords
project management education; metaverse; technology-based education; virtuality; simulation.

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1. Introduction

The Fourth Industrial Revolution (4IR), characterized by the convergence of technologies like artificial intelligence (AI), big data, automation, and the metaverse, fundamentally reshapes industries globally. In today's dynamic business and technological landscape, the ability to enhance information systems (IS) provides a crucial competitive edge (Varajão et al., 2021). This transformation necessitates a parallel evolution in educational systems to equip the workforce with the requisite skills and competencies. This need is particularly pronounced in project management (PM), a field increasingly reliant on digital tools, virtual collaboration platforms, and agile methodologies. Traditional, face-to-face learning approaches are becoming insufficient to prepare project managers for the demands of this rapidly digitizing landscape.

The emergence of the metaverse, an interconnected and immersive virtual world, presents a compelling opportunity to revolutionize PM education. By offering interactive, hands-on learning experiences that closely simulate real-world project scenarios, the metaverse has the potential to bridge the gap between theory and practice. This immersive environment can foster enhanced student engagement, promote the development of crucial skills like decision-making, communication, and leadership within virtual teams, and facilitate a deeper understanding of complex project dynamics. As highlighted by Schwab (2017), the convergence of 4IR technologies demands a holistic approach to workforce preparation, extending beyond AI to encompass digital literacy, systems thinking, and proficiency in emerging digital tools. The metaverse offers a platform to cultivate these broader skill sets within a dynamic and engaging context.

However, the integration of the metaverse into PM education is not without its challenges. Technological limitations, accessibility concerns, the learning curve associated with new digital tools, and the need for curricular adjustments pose significant hurdles. Furthermore, as projects increasingly involve geographically dispersed teams operating in fully digital environments, understanding the nuances of virtual team dynamics within the metaverse becomes crucial. Dispersed teams are spread across different locations but may still use traditional communication methods like email or phone, occasionally meeting in person. Virtual teams, however, operate fully in digital environments, relying entirely on tools like video conferencing and messaging for collaboration, with no in-person meetings. The increasing prevalence of virtual and hybrid work models underscores the critical need for virtual teams (VTs) to effectively communicate, collaborate, and deliver projects. Therefore, VTs must understand the unique challenges and success factors of virtual project execution, and may require additional training to adapt to these new working methods (Swart et al., 2022). This study differentiates between dispersed teams, which may utilize traditional communication methods alongside digital tools, and virtual teams, which operate exclusively within digital spaces. The focus here is on virtual teams, recognizing the metaverse's unique capacity to foster immersive, real-time collaboration irrespective of physical location.

This paper investigates the potential of the metaverse to enhance PM education, exploring its applications, impact on learning outcomes and student engagement, and the challenges associated with its implementation. It also considers the evolving nature of project management frameworks and standards in response to digital transformation. By examining the perspectives of project management practitioners, this study aims to contribute to the development of innovative training tools, environments, and approaches that effectively prepare future project managers for the demands of the 4IR. Specifically, this research addresses the following key questions:

(RQ1) How can the metaverse enhance student engagement and learning outcomes in PM education?

(RQ2) What are the benefits and challenges of using metaverse technologies in PM training, according to educators and industry professionals?

(RQ3) How can the metaverse support the development of essential project management skills?

(RQ4) What are the practical and technological barriers to implementing metaverse-based education, and how can they be addressed?

(RQ5) How can the metaverse be integrated into existing curricula to offer a blended learning experience?

To meet the research objectives, this study adopted an exploratory approach involving project managers across various industries. Participants were engaged in a virtual task designed to simulate real-world project management scenarios within a metaverse environment. This task enabled project managers to collaborate, make decisions, and experience immersive project simulations, providing valuable insights into the practical applications of metaverse technologies in professional settings. Through this design, the study aimed to explore how the metaverse can enhance learning, engagement, and skills development within project management education. The findings from this case study will guide the future implementation of metaverse technologies in both educational and professional environments.

This paper is organized into five distinct sections. Firstly, it provides a comprehensive background on metaverse technology, emphasizing its relevance within the educational and project management domains. Secondly, it outlines the research methodology and describes the implementation of the metaverse-based task. Subsequently, it presents and analyzes the results and findings derived from the project managers' experiences. The fourth section critically discusses the implications of these findings for contemporary project management education. Finally, the paper concludes by exploring future opportunities and offering valuable recommendations for the successful adoption of metaverse technologies within educational frameworks.

2. Literature Review

The accelerating pace of technological innovation, particularly within the framework of the Fourth Industrial Revolution (4IR), has initiated profound shifts across various sectors, including project management. These technological advancements have not only transformed industrial practices but have also redefined educational methodologies, demanding a reassessment of traditional pedagogical approaches. In particular, the emergence of the metaverse as an immersive virtual environment has introduced new possibilities for enhancing the teaching and learning of project management. This literature review aims to critically examine existing scholarship on digital transformation, virtual learning environments, and their pedagogical applications, with a specific focus on how immersive technologies such as the metaverse can reshape project management education. By synthesizing current research, this section seeks to identify the theoretical underpinnings, practical benefits, and challenges associated with integrating the metaverse into educational frameworks, thereby offering insights into future research directions and potential pedagogical innovations.

2.1. Transformation of project management environment: Virtuality

The concept of virtuality has become increasingly central to project management due to the rise of geographically dispersed teams and reliance on digital communication technologies. Virtuality, as defined in the literature (Adams & Adams, 1997; Khazanchi & Zigurs, 2005; Krill & Juell, 1997), encompasses various dimensions of dispersion, including time, organizational affiliation, culture, team continuity, experience, availability, and technology variability. Even individuals within the same physical location may engage in virtual projects due to scheduling conflicts, highlighting the communication and team-building challenges associated with increased distance (Adams & Adams, 1997). A virtual project is essentially a collaborative effort conducted remotely to achieve a shared goal (Krill & Juell, 1997), involving virtual teams that operate across space, time, and organizational boundaries, connected through communication technologies and engaging in interdependent tasks with a common purpose (Hofer, 2009; Lipnack & Stamps, 2008). This shift towards virtual teams necessitates the integration of virtuality and a heavy reliance on communication technologies, challenging traditional team structures to adapt to modern workplaces. As highlighted by Hofer (2009), virtual teams represent an innovative organizational paradigm characterized by flexibility and responsiveness, where technology plays a pivotal role in managing geographically dispersed projects. In this context, virtuality can be understood through three dimensions: spatial virtuality (working from different locations using digital tools), temporal virtuality (asynchronous work across time zones), and technological virtuality (leveraging advanced digital platforms for communication, resource sharing, and project tracking). This study focuses on this shift towards technology-enabled, distributed teams, positioning the metaverse as a potential solution for enhancing collaboration and engagement within immersive 3D environments.

2.2. Competencies for project management in 4IR: Navigating success

The growing importance of project management (PM) has led to increased resource allocation, project-based work organization, more projects, stronger links between projects and strategy, and greater PM scope and complexity (Micán et al. 2020). Project managers play a crucial role in ensuring project success (Chen et al., 2019; Ekrot et al., 2016; Irfan et al., 2021; Karanja & Malone, 2021). Given the reported high project failure rates (Chen & Bozeman, 2012; Pfeifer, 2011), identifying the essential competencies for project managers has become a key area of research. The Project Management Institute (PMI) also highlights a growing gap between job growth and the availability of qualified professionals (PMI, 2021). Project managers navigate ambiguous situations, uncertainty, and conflicting demands (Sandberg et al., 2022), necessitating agility and creativity to overcome the resulting environmental and technical challenges (Pires & Varajão, 2024).This necessitates a combination of soft skills (communication, negotiation, leadership, team building, and contextual awareness) and hard skills (domain-specific knowledge and technical expertise in scope, time, cost, and quality management) (Atkinson, 1999; Pant & Baroudi, 2008). While both skill sets are important, soft skills are often considered more influential in achieving successful project outcomes (Alvarenga et al., 2019; De Araújo & Pedron, 2015; Moradi et al., 2020; Ramazani & Jergeas, 2015). Therefore, project management training programs must consider this comprehensive skill set to foster proficiency at individual, team, organizational, and societal levels (Gareis & Huemann, 2007).

2.3. Project management education and training: Addressing the discrepancies

The rise of project-based work and digital transformation has created a project management talent shortage (Cabot & Gagnon, 2021). The increasing demand for skilled project management professionals has led to the development of various educational and developmental programs (Umpleby & Anbari, 2004). This has included the rise of formal undergraduate and graduate programs in project management (Bredillet et al., 2013; Lloyd-Walker et al., 2016). While recognized standards from organizations like PMI, APM, and IPMA provide essential core concepts and principles (Delle-Vergini et al., 2023), criticisms persist regarding the effectiveness of current project management education. Scholars argue for a paradigm shift to better align education with practical application (Atkinson, 2008; Egginton, 2012; Ojiako et al., 2011), as current approaches are deemed insufficient to meet the needs of modern organizations in the face of high project failure rates and increasing global complexity (Córdoba & Piki, 2012; Ojiako et al., 2011). Traditional project management education often relies on lecture-based instruction, textbook learning, and limited integration of digital tools, emphasizing standardized frameworks like the PMBOK® Guide and focusing on theoretical knowledge and technical skills (Mason et al., 2009; Ramazani & Jergeas, 2015; Thomas & Mengel, 2008; Tumpa et al., 2023). This approach often neglects practical application, digital collaboration tools, and essential soft skills (Cicmil et al., 2006; Ewin et al., 2017; Pant & Baroudi, 2008; Winter et al., 2006). As industries evolve due to technological advancements and the shift to remote teams, these outdated models are increasingly inadequate. There is a recognized need for a shift in teaching and learning approaches to address the gap between current educational practices and the demands of contemporary businesses (Córdoba & Piki, 2012; Karanja & Malone, 2021; Thomas & Mengel, 2008). While project management education varies across industries, there is a growing emphasis on digital skills to manage increasingly digital, virtual, and dispersed teams. Identifying the most vital competencies for project management students and graduates entering the workforce is crucial (Kearney et al., 2024).

2.4. Past and future of education

The evolution of the education context encompasses various changes and developments over time (Table 1). This includes shifts in teaching methods, technological advancements influencing learning environments, changes in educational policies, and adaptations to meet the evolving needs of learners and society.

Table 1. Evolution of education context

Era	Educational Changes	Project Management Era
1st Industrial Revolution (Empirical Stage)	The evolution of labor specializations marked a shift towards specialized skills. Subsequently, trade schools were established to provide targeted vocational training. The establishment and growth of technical universities further solidified the formal education system in specialized technical and scientific fields.	Project Management 1.0
2nd Industrial Revolution (Gannt Chart)	The establishment of a multi-level training system for industry marked a strategic approach to workforce development. This included the standardization of training procedures, contributing to a more uniform and quality educational experience. Consequently, these efforts played a crucial role in elevating the reputation of technical education.	Project Management 2.0
3rd Industrial Revolution (CPM, PERT, GERT, EVM)	The integration and globalization of education have led to the development of academic mobility, fostering the movement of students and professionals across borders. This transition is accompanied by the adoption of international education standards. Additionally, in response to global trends, there is an increasing emphasis on training specialists for service-oriented fields.	Project Management 3.0
4th Industrial Revolution (AI, Machine Learning, IoTs)	The individualization and virtualization of education reflect a shift towards personalized learning experiences and digital platforms. This transformation also involves reinforcing the project-based and multidisciplinary nature of technical education, emphasizing practical and collaborative aspects. Furthermore, the development of interactive educational resources enhances engagement and facilitates dynamic learning environments.	Project Management 4.0

Source: Compiled from the studies of references Bühler et al., 2022 and Aliu et al., 2023

The historical progression of industrial revolutions has significantly shaped the landscape of education. The first industrial revolution, fueled by the steam engine, led to the emergence of labor specializations, trade schools, and the development of technical universities. In the second industrial revolution, powered by electricity, multi-level training systems for industry were established, training became standardized, and the prestige of engineering education soared (Bühler et al., 2022). The third industrial revolution, driven by information technology, brought about the integration and globalization of education, increased academic mobility, and the development of international educational standards (Sakhapov & Absalyamova, 2018). Considering the profound changes brought by the 4IR, the training requirements for the technical profession are expected to undergo substantial transformation (Goldin & Katz, 2018). According to Schwab (2017), the 4IR is fundamentally altering the way we live, work, and learn, creating an urgent need for educational reforms to prepare the workforce for a future defined by complex technologies and innovative business models. In the context of project management education, Gonçalves et al. (2023) emphasize that traditional curricula are increasingly seen as insufficient, as they do not adequately reflect the technological and collaborative skills required in modern project environments. According to a recent study by Fernández-Sánchez et al. (2022), the curricular integration of digital technologies in teaching has become a critical factor for modernizing education, particularly at non-university levels. This shift is crucial for enabling educators to equip students with the skills necessary to navigate the digital landscape effectively. In alignment with this, educational reforms need to focus not only on the adoption of digital tools but also on the development of teachers' digital competencies and ongoing professional training. To effectively address the challenges posed by an increasingly complex and hyper-connected world, there is a collective need to fundamentally rethink or even reinvent the project management profession and the underlying education system. In the recent era of the 4IR, creative convergence education has witnessed notable trends, prompting a surge in studies proposing educational models aimed at fostering students' creative and critical meaning-making processes (Kettler et al., 2021). In the current modern era, it is crucial to utilize innovative approaches within the field of project management education (Carreiro & Oliveira, 2018; Hunady et al., 2022; Oliveira et al., 2020).

2.5. Traditional vs Metaverse-based education

The evolution of education has been significantly shaped by successive industrial revolutions (Bühler et al., 2022; Carreiro & Oliveira, 2018; Goldin & Katz, 2018; Kettler et al., 2021; Oliveira et al., 2020; Sakhapov & Absalyamova, 2018). The pandemic-driven adoption of collaboration technologies, coupled with metaverse advancements, has increased comfort with advanced online learning tools, and this, along with the 4IR, requires a rethinking of project management and its education (Mitchell, 2024). Traditional education and metaverse-based education are distinct paradigms, each with unique advantages and limitations. While traditional education often relies on hierarchical classroom structures, lectures, and memorization, contemporary project management curricula incorporate interactive techniques like workshops, case studies, and simulations. However, traditional education still faces limitations in preparing students for the technology-driven landscape of modern project management. The metaverse offers an evolution in digital learning environments, providing immersive, interactive experiences with realistic simulations, global collaboration, and enhanced engagement and retention. A comparison of both approaches according to their basic characteristics is given in Table 2.

Table 2. Traditional education vs. metaverse-driven education

Aspect	Traditional Education	Metaverse-based Education
Access	Limited Access	Enhanced Access
Location	Physical classrooms	Unrestricted by geographical/physical constraints
Interaction	Limited	Increased
Collaboration	Limited opportunities	Enhanced opportunities
Learning Materials	Traditional (textbooks and physical resources)	Digital learning materials
Personalization	Limited	Customized/adaptive learning
Flexibility	Fixed schedules and rigid structures	Flexible schedules and structures
Immersive Learning	Limited	Enhanced
Social Interaction	Limited	Increased
Teacher-Student Relationship	Physical presence	Virtual presence
Cost	Traditional education expenses	Reduced costs for infrastructure and commuting
Global Collaboration	Limited opportunities	Enhanced global collaboration
Teaching Form	One-to-many	One-to-many, One-to-one
Educator	Teacher	Knowledge sharer
Learner Identity	Authentic identity	Tailored and digital identity
Time	At a scheduled time by the class timetable	Without being limited by time
Learners Interact with	Genuine instructors and classmates	Authentic educators and fellow students in physical form, or virtual educators and peers
Learning Scene	Authentic learning environments	Virtual learning environments
Learning Resource	Printed or multimedia learning resources that learners usually cannot interact with (book, pen, whiteboard, smartboard, etc.)	Visualized or decentralized learning resources that allow learners to interact (human-computer interface, wearable devices)
Learning Activity	Lecture-oriented with opportunities for learner engagement through a series of activities and collaboration with peers	Predominantly composed of contextualized learning activities within 3D learning environments, enabling learners to engage in virtual learning activities

Aspect	Traditional Education	Metaverse-based Education
Learning Objective	To develop low-order cognitions	To develop high-order cognitions, achieve more comprehensive learning objectives
Learning Assessment	Learning outcomes derived from summative data, relying on traditional exams and assessments.	Integrate formative and summative data, prioritizing learners' growth, and employ diverse assessment methods with real-time feedback.

Source: Compiled from the studies of references Alfiras et al., 2023; Zhang et al., 2022; Lin et al., 2022; Rohan et al., 2023

Compared to platforms like Moodle, which offer primarily passive learning experiences, the metaverse provides real-time, interactive simulations and collaboration in 3D spaces. While traditional education excels in foundational knowledge, metaverse-based education offers immersive, interactive, and personalized learning, addressing many of the limitations of traditional approaches (Meena et al., 2023; Soni & Kaur, 2023). However, challenges such as technological barriers, digital fatigue, learning curves, and potential social isolation must be addressed.

To sum up, traditional education excels in discipline and foundational knowledge but may limit critical thinking and practical application. Metaverse-based education, marked by immersion, interactivity, and personalization, signifies a paradigm shift addressing traditional education's limitations. It introduces innovative learning approaches, enhancing engagement, interactivity, and accessibility, thereby reshaping the educational experience.

2.6. Metaverse for project management education

The metaverse, a collective, virtual shared space combining virtual and physical reality, offers significant opportunities for project management education. It allows for immersive learning and simulations, enhanced collaboration and communication, virtual project scenarios and role-playing, real-time data and project monitoring, and global team management. By integrating the metaverse, educators can enhance engagement, collaboration, and personalized learning. Designing metaverse-driven education requires a diverse set of competencies, including technical proficiency, pedagogical expertise, instructional design skills, creativity, and adaptability. While AI can assist in certain aspects of course design, human course authors remain essential for crafting meaningful and engaging learning experiences. The metaverse can provide significant gains in project management education (Table 3).

Table 3. Strategies and tools for maximizing the metaverse in project management education

Approach/Tool	How to use	Possible Gains
Increased Engagement Through Immersive Learning	Create virtual 3D classrooms within the metaverse where students can immerse themselves in project management scenarios.	The immersive environment allows students to explore and interact with 3D objects and avatars, enhancing engagement and making learning more captivating.
Expanded Access and Collaborative Learning	Leverage the metaverse for collaborative learning, allowing students worldwide to participate in virtual classes and engage in real-time project collaboration.	This fosters diversity and inclusivity, breaking down geographic barriers and promoting global collaboration among students.
Personalized Learning with Competence-Based Education	Leverage the metaverse's ability to analyze data on student performance and behavior for personalized learning experiences.	The metaverse adjusts to individual student needs, providing tailored feedback and content. Competence-based education in the metaverse ensures a focus on essential skills for project management.
Innovative Assessment Methods	Explore new assessment methods in the metaverse, such as simulations and games, to evaluate student learning	These assessments, reflective of real-world scenarios, can be more engaging and offer a comprehensive understanding of students' project management skills.

Approach/Tool	How to use	Possible Gains
Integration of Advanced Technologies	Incorporate virtual reality, augmented reality, and artificial intelligence into the metaverse learning environment	These advanced technologies enhance personalization and adaptability, helping students grasp complex project management concepts, develop critical skills, and prepare for real-world scenarios.
Blended Learning and Interdisciplinary Approach	Embrace blended learning by combining traditional open learning with online training within the metaverse	The metaverse breaks down subject barriers, promoting interdisciplinary learning, essential for a holistic understanding of project management.
Seamless Integration of Physical and Virtual Learning	Integrate virtual reality with traditional learning methods	This seamless integration caters to various learning styles and provides personalized support, overcoming the limitations of traditional teaching methods.
Promoting Social Connection and Collaboration	Leverage the social aspects of the metaverse to enhance collaboration and group interaction.	Learning environments within the metaverse cultivate a community atmosphere, promoting the exchange of ideas and facilitating collaborative problem-solving—a fundamental aspect of developing essential skills for project management.
Utilizing Metaverse for Specialized Training	Explore the metaverse's potential for specialized training programs that may be challenging or dangerous in the real world	Overcome limitations such as time, space, or safety concerns, providing effective training programs for project management skills.
Addressing Challenges and Ethical Considerations	Acknowledge challenges in creating and implementing the metaverse in education, including technological limitations and ethical considerations	A proactive approach to addressing challenges ensures a more sustainable and ethical implementation of metaverse-based project management education.

Source: Compiled from the studies of Ho & Lee, 2023; Soni & Kaur, 2023; Cui et al., 2023; Raj et al., 2023; Hwang & Chien, 2022

Course authors designing metaverse-driven education for project management will need a diverse set of competencies. First, they must have technical proficiency to understand the technologies behind virtual environments, such as metaverse platforms and immersive simulations. This includes knowledge of tools used for creating 3D models and interactive virtual spaces. Additionally, pedagogical expertise is essential, as authors must adapt traditional project management concepts to virtual formats while ensuring the content is engaging and promotes critical thinking. Instructional design skills will also be crucial, as authors will need to create learner-centered curricula that integrate immersive simulations, role-playing, and real-time decision-making exercises. Creativity and adaptability are equally important, as course authors will need to design innovative learning experiences and adapt quickly to new technological advancements. Collaboration with technologists and game designers will also be necessary to develop realistic and interactive virtual project environments. As for whether AI will replace course authors, while AI can assist in certain aspects of course design, such as content generation, grading, or personalizing learning paths, it is unlikely to fully replace human authors. AI can streamline tasks and enhance educational efficiency, but course authors bring critical pedagogical insight, creativity, and the ability to contextualize learning within specific industries or educational settings. While AI will play an increasingly supportive role, course authors will remain essential for crafting meaningful, nuanced, and engaging learning experiences.

In conclusion, the metaverse presents a transformative opportunity to enhance project management education by providing immersive, interactive, and collaborative learning experiences that address the evolving demands of the 4IR. But in addition to the issues of accessibility and technical barriers, there are concerns about the over-reliance on technology in educational settings. Prolonged engagement in virtual environments may contribute to digital fatigue, and the lack of face-to-face interaction could lead to a decrease in empathy and interpersonal communication skills, which are essential for project managers.

Moreover, while the metaverse offers exciting possibilities for immersive learning, there is the risk that it could reinforce isolation, especially for students who already struggle with the lack of in-person contact in online learning environments. It is essential for educators to recognize these challenges and develop strategies to ensure that metaverse-based education does not replace, but rather complements, the social and interactive aspects of traditional learning methods.

3. Research Methodology

This study employed a qualitative research design to explore project managers' perspectives on the potential of the metaverse in project management education. This approach allowed for a rich understanding of their experiences, insights, and opinions regarding this emerging technology.

3.1. Participants

A total of 32 project managers participated in the study. Participants were selected using a combination of convenience and snowball sampling techniques. Initial contacts were made through professional networks, including LinkedIn and project management forums, with subsequent referrals from initial participants expanding the pool. This sampling strategy facilitated access to a diverse range of perspectives from professionals with varying backgrounds and experiences. The participant group represented a range of industries, including IT (10 participants), engineering and construction (8), finance and banking (5), healthcare (4), manufacturing (3), and other sectors (2). This industry diversity ensured a broad perspective on the applicability of the metaverse across different project contexts. Participants also represented both small-to-medium enterprises (SMEs, 14 participants) and large multinational corporations (MNCs, 18 participants), providing insights from different organizational scales. Geographically, the majority of participants were based in North America (12) and Europe (10), with smaller representations from Asia (6) and other regions (4). Participants' project management experience ranged from 5 to 20 years, with 10 having 5-10 years, 12 having 10-15 years, and 10 having 15-20 years of experience. This range allowed for the capture of both recent and more established perspectives on project management practices and educational needs. Notably, 15 participants were involved in project management education in some capacity (e.g., as trainers, mentors, or in academia), while 17 were not directly involved. In terms of familiarity with the metaverse, 8 participants were highly familiar (having used VR tools or metaverse platforms), 14 were moderately familiar (with basic knowledge but limited practical experience), and 10 were not familiar. This distribution allowed for an assessment of the metaverse's potential from varying levels of exposure.

3.2. Data Collection

Data was collected through semi-structured interviews conducted online via Zoom and Microsoft Teams. These interviews, lasting between 25 and 30 minutes, allowed for in-depth exploration of participants' views. The interviews were guided by open-ended questions designed to elicit detailed responses regarding the potential role of the metaverse in project management education. These questions focused on areas such as the benefits and challenges of metaverse adoption, its impact on skill development (particularly soft skills), and considerations regarding technological barriers, accessibility, and the learning curve associated with new digital tools.

3.3. Data Analysis

Thematic analysis was employed to analyze the interview data, following Braun and Clarke’s (2006) guidelines. This involved several stages:

- Familiarization: All interviews were transcribed verbatim and thoroughly reviewed to gain a deep understanding of the data.

- Coding: Data was systematically coded using both inductive (codes emerging from the data) and deductive (codes based on the research questions) approaches. NVivo qualitative analysis software was used to manage the coding process.
- Theme Development: Similar codes were grouped to identify broader themes related to the research questions, such as engagement and immersion, technological challenges, the impact on project management skills, and the future of education.
- Theme Review and Refinement: The identified themes were reviewed and cross-checked against the original transcripts to ensure they accurately reflected the participants' views.
- Theme Definition and Naming: Each theme was clearly defined and given a descriptive name, such as "Immersive Learning," which captured the metaverse's ability to create engaging virtual environments.

To provide context and deeper interpretation, relevant literature, including the sensemaking and sense giving framework by Gioia and Chittipeddi (1991), was integrated into the analysis. Verbatim quotes from the interviews were used to support the identified themes and ensure the findings offered meaningful interpretations grounded in the participants' experiences. Data saturation was reached after 28 interviews, as no new themes emerged in subsequent interviews; however, all 32 interviews were completed to ensure comprehensive data collection. This rigorous approach to data analysis ensured the credibility and validity of the study's findings.

4. Findings

This study employed thematic analysis to systematically analyze interview data and accurately capture the perspectives of participants. The research commenced with a thorough familiarization phase, involving a meticulous review of all interview transcripts to gain a deep understanding of the data and identify initial patterns. Subsequently, a systematic coding process was undertaken, incorporating both inductive and deductive approaches. Inductive coding allowed for the emergence of data-driven themes, while deductive coding ensured the systematic application of codes relevant to the research questions. Thematic analysis of the interview data revealed four primary themes: (A) Problems of Present Project Management Education, (B) Recommendations for Enhancing Current Project Management Education, (C) Potential of the Metaverse in Project Management Education, and (D) Obstacles in Metaverse Adoption for Project Management Education. These themes were rigorously reviewed and validated against the original interview transcripts to ensure data saturation – a point at which no new themes or insights emerged. Verbatim quotes were incorporated throughout to provide concrete examples and support the identified themes. Through this rigorous process, the study ensured that the findings were grounded in the participants' experiences and provided valuable insights into the potential and challenges of integrating the metaverse into project management education.

4.1. (A) Problems of present project management education

Participants identified several key shortcomings in current project management education, highlighting a need for improvement across various dimensions:

Lack of Standardized Curriculum and Outdated Content: Inconsistencies in curriculum quality across institutions and outdated course content that fails to reflect current industry practices and technological advancements were frequently cited. Participants emphasized the need for better alignment between academic curricula and industry certifications.

> "One of the challenges is the lack of standardized curriculum across institutions, leading to inconsistencies in the quality of project management education worldwide."
>
> "A lack of alignment between academic curriculum and industry certifications creates a gap in recognizing and valuing the skills acquired through formal education."

> "Global project management education faces issues with outdated course content that doesn't always align with the rapidly evolving industry practices and technological advancements."

> "The challenge of keeping course content relevant to diverse industries; a one-size-fits-all approach may not cater to the unique needs of different sectors."

Limited Emphasis on Practical Application: A strong emphasis on theory at the expense of practical application was a recurring concern. Participants stressed the importance of hands-on experience and the need for programs to incorporate more real-world scenarios and adaptive project management methodologies.

> "A significant problem is the limited emphasis on practical application; many programs focus heavily on theory, leaving students unprepared for real-world project scenarios."

> "There's a need for more emphasis on teaching adaptive project management methodologies to better prepare professionals for dynamic and unpredictable project environments."

Insufficient Integration of Technology: Participants noted a need for better integration of digital tools and technologies into project management education to keep pace with industry practices. They also highlighted inconsistencies in the use of technology across educational institutions.

> "There's a need for better integration of technology in project management education, as many programs struggle to keep pace with the digital tools used in the industry."

> "Inconsistent use of technology platforms and tools across educational institutions hampers the development of a unified and streamlined learning experience for students."

Inadequate Soft Skills Development: Insufficient emphasis on developing crucial soft skills such as communication, leadership, emotional intelligence, and cross-cultural communication was identified as a significant gap.

> “Insufficient interpersonal skills like communication and leadership holds back project managers from being fully ready for the global workforce.”

> "Not giving enough attention to the importance of emotional intelligence in project management education can hold back the development of effective leadership and team management skills.”

> “Neglecting cross-cultural communication skills in project management education could hamper effective collaboration in our globalized business world.”

Limited Industry Exposure and Internships: Participants highlighted the lack of real-world industry exposure and practical internship opportunities, hindering graduates' transition into professional roles.

> “Many programs not offering real-world industry exposure and hands-on internships make it tough for grads to smoothly shift into professional project management roles. Getting practical experience is key for a smoother transition from school to the job.”

> “When academia and industry don't collaborate enough, there's a gap in understanding current industry needs, making it hard to churn out graduates with the right skills.”

Accessibility, Sustainability, and Ethical Considerations: Concerns were raised regarding accessibility of quality education, particularly in resource-limited regions, as well as inadequate attention to sustainability and ethical considerations in project management practices.

> "Issues with accessibility, particularly in regions with limited educational resources, pose a barrier to aspiring project managers who may not have equal opportunities for quality education."

> "Some programs struggle to accommodate the increasing demand for project management education, leading to potential compromises in quality."

Lack of Emphasis on Continuous Learning and Emerging Trends: Participants noted that current programs often overlook the importance of continuous learning and staying updated with emerging trends in the field.

> "Global project management education often overlooks the significance of continuous learning and staying updated with emerging trends, putting professionals at a disadvantage."

> "The challenge of incorporating real-time project management experiences into the curriculum to expose students to the fast-paced nature of the industry."

Insufficient Focus on Risk Management Education: Participants felt that current programs do not adequately prepare students for the complexities and uncertainties inherent in project management, particularly regarding risk management.

> "An insufficient focus on risk management education in many programs leaves graduates unprepared for the complexities and uncertainties inherent in project management."

> "Problems with outdated assessment methods; many programs still rely heavily on traditional exams rather than incorporating practical, real-world assessments."

4.2. (B) Recommendations for enhancing current project management education

Based on their experiences, participants offered several recommendations for improving project management education:

Increased Practical Application and Real-World Relevance: Participants strongly advocated for integrating more practical case studies, interactive workshops, simulation tools, leadership practice opportunities, and critical thinking exercises based on real-world scenarios.

> "Integrating more practical, real-world case studies would enhance the relevance of project management education."

> "Implementing interactive workshops that allow students to apply theoretical knowledge in a practical setting."

> "Providing access to simulation tools that allow students to experience the challenges of managing complex projects."

> "Offering more opportunities for students to practice leadership roles in project scenarios."

> "Encouraging critical thinking by presenting students with complex, real-world scenarios to solve."

Emphasis on Agile Methodologies: Given the dynamic nature of modern projects, participants recommended an increased focus on teaching agile methodologies.

> "Increasing focus on teaching agile methodologies to adapt to the fast-paced nature of modern projects."

Collaboration with Industry Experts: Participants suggested collaborating with industry experts for guest lectures and encouraging student participation in industry conferences and networking events.

> "Collaborating with industry experts for guest lectures to provide students with insights into current project management practices."

> "Encouraging students to participate in industry conferences and networking events for real-world exposure."

Integration of Technology-Focused Coursework: Participants recommended incorporating more technology-focused coursework, including access to industry-standard project management tools and courses on emerging technologies like AI and blockchain.

> "Incorporating more technology-focused coursework to prepare students for the digital transformation in project management."

> "Providing access to industry-standard project management tools to familiarize students with practical applications."

> "Introducing courses on emerging technologies like artificial intelligence and blockchain in project management."

Stronger Emphasis on Soft Skills: Participants emphasized the need for a stronger focus on developing soft skills such as communication, leadership, and conflict resolution, including emotional intelligence.

> "Including a stronger emphasis on soft skills such as communication, leadership, and conflict resolution."

> "Highlighting how being tuned into emotions is key for rocking project management, especially when you've got a cool team dynamic going on."

Interdisciplinary Projects and Collaboration: Participants recommended incorporating interdisciplinary projects and fostering collaboration with other business functions.

> "Providing opportunities for students to work on interdisciplinary projects to simulate real-world project environments."

> "Promoting more collaboration among students through team-based projects to develop effective teamwork skills."

> "Encouraging more interdisciplinary collaboration with other business functions like marketing and finance."

Emphasis on Continuous Learning: Participants stressed the importance of continuous learning and professional development throughout a project manager's career, including regularly updating course content to reflect the latest trends.

> "Emphasizing the importance of continuous learning and professional development throughout a project manager's career."

> "Regularly updating course content to keep up with the latest trends and advancements in project management."

Experiential Learning Opportunities: Participants advocated for implementing experiential learning opportunities, such as internships, to bridge the gap between theory and practice.

> "Implementing experiential learning opportunities, such as internships, to bridge the gap between theory and practice."

4.3. (C) Potential of the metaverse in project management education

Participants expressed strong support for integrating the metaverse into project management education, highlighting its potential to:

Provide Immersive Learning and Practical Application: Participants believed the metaverse's immersive simulations would allow students to apply theoretical concepts in practical, risk-free environments, facilitating experimentation with different project strategies.

> "Absolutely, the metaverse can revolutionize project management education by providing immersive simulations, allowing students to practically apply theoretical concepts."

> "Yes, metaverse-based project simulations can offer a safe space for students to experiment with different strategies and approaches in project execution."

> "Metaverse-enabled resource management simulations can help students understand the complexities of allocating resources in real projects."

Facilitate Global Collaboration and Connectivity: Participants recognized the metaverse's potential to foster global collaboration through virtual events, forums, and career fairs, connecting students with professionals worldwide.

> "I believe the metaverse is essential in project management education for fostering global collaboration, enabling students to work together seamlessly regardless of geographical locations."

> "Absolutely, metaverse-based networking events can connect students with industry professionals, expanding their professional circles and opportunities."

> "Metaverse forums can connect students with professionals, creating a space for knowledge exchange and networking."

> "Imagine metaverse career fairs as your shortcut to landing cool project management gigs! You get to connect with potential employers and snag direct job opportunities."

Offer Hands-on Experience in Risk-Free Environments: Participants highlighted the metaverse's potential for virtual project setups and virtual internships, allowing students to gain practical experience without real-world risks.

> "The metaverse offers a dynamic platform for virtual project environments, enabling students to gain hands-on experience in a risk-free setting."

> "The metaverse should be used for virtual internships, allowing students to work on real projects and build practical skills under simulated conditions."

Prepare Students for Real-World Challenges: Participants believed metaverse-driven role-playing scenarios and case studies could effectively simulate real-world project challenges, preparing students for the unpredictable nature of project management.

> "Metaverse-driven role-playing scenarios can simulate real-world project challenges, preparing students for the unpredictable nature of project management."

> "Yes, metaverse case studies can present students with diverse project scenarios, preparing them for a wide range of challenges in their careers."

> "Yes, metaverse-based hackathons focused on project management challenges can stimulate creative problem-solving among students."

> "Utilizing the metaverse for guest lectures and industry expert sessions can bring real-world insights into the classroom, enhancing the educational experience."

Enable Flexible Learning and Certification Programs: Participants acknowledged the metaverse's ability to support asynchronous learning and advocated for the integration of metaverse-based certification programs.

> "Yes, metaverse platforms can facilitate asynchronous learning, providing flexibility for students to access project management content at their own pace."

> "Implementing metaverse-based certification programs can offer students industry-recognized qualifications, boosting their credibility in the job market."

Enhance Collaboration and Teamwork: Participants emphasized the metaverse's role in strengthening teamwork and decision-making skills through collaborative project planning exercises.

> "Using the metaverse for collaborative project planning exercises can enhance teamwork and decision-making skills among students."

Increase Engagement through Gamification and Interactive Learning: Participants supported the use of gamification in the metaverse to make learning more engaging and interactive.

> "The metaverse should be integrated into project management education through gamification, making learning engaging and interactive."

> "Adding metaverse vibes to project management classes can spice up the learning game, making it more fun and getting students more into it."

Support Continuous Professional Development: Participants saw the metaverse as a valuable platform for continuous professional development, keeping project managers updated on industry trends and best practices.

> "Think of using metaverse platforms for pro development like scoring project managers a VIP pass – it keeps them in the loop on the latest industry trends and best practices."

> "Adding metaverse tech to project management courses is like gearing up students for the digital tool takeover in the industry."

Facilitate Feedback Loops and Project Retrospectives: Participants acknowledged the metaverse's potential for providing continuous feedback in project simulations and conducting project retrospectives.

> "Using the metaverse for constant feedback in project simulations is like turbocharging students' decision-making skills."

> "Analyzing projects through the metaverse can uncover key lessons from both triumphs and failures in project strategies."

Enable Real-Time Monitoring, Evaluation, and Feedback: Participants noted that metaverse applications could enable real-time project monitoring and reporting, providing a comprehensive understanding of project progress.

> "Metaverse platforms can be used for real-time project monitoring and reporting, allowing students to understand project progress at a glance."

> "Utilizing the metaverse for continuous feedback loops in project simulations helps students refine their decision-making skills, promoting iterative learning."

> "The metaverse supported project retrospectives provide valuable insights into successful and unsuccessful project strategies, fostering a culture of continuous improvement."

> "Real-time project monitoring and reporting in the metaverse allow students to understand project progress at a glance."

> "Continuous feedback loops in metaverse project simulations help students refine their decision-making skills."

Offer Specialized and Industry-Specific Learning: Participants believed the metaverse could facilitate industry-specific project simulations, customizing education to address real-world challenges in different sectors.

> "Adding metaverse tech to project management courses is like giving students a heads-up for the rising use of digital tools in the industry, syncing up education with what's trending in the field."

> "Metaverse-enabled resource management simulations help students understand the complexities of allocating resources in real projects, a critical skill in project management."

> "Mixing in metaverse platforms for industry projects is like customizing education to fit each sector's unique challenges."

Broaden Project Exposure and Communication Skills: Participants suggested that exploring case studies and engaging in virtual study groups and project showcases in the metaverse could enhance communication and presentation skills.

4.4. (D) Obstacles in metaverse adoption for project management education

Despite the recognized potential, participants also identified several obstacles to metaverse adoption:

Financial and Infrastructure Hurdles: Participants expressed concerns about the upfront costs for technology and training, as well as the potential digital divide due to unequal access to hardware and internet connectivity.

> "A major snag we're facing is the upfront investment needed for the tech and training. It could cause some financial headaches for our educational institutions."

> "Not all students may have access to the necessary hardware and high-speed internet, creating a potential disparity in learning opportunities."

Integration Challenges with Existing Curricula: Participants noted potential difficulties in integrating the metaverse into existing curricula and aligning it with traditional teaching methods, as well as a lack of standardization across metaverse platforms.

> "Integration into existing curricula can be a hurdle as it requires redesigning courses and ensuring compatibility with traditional teaching methods."

> "Limited standardization in metaverse platforms may create compatibility issues and make it challenging to establish consistent educational experiences."

Security and Privacy Concerns: Participants raised concerns about data security and privacy, particularly when handling sensitive project information within the metaverse.

> "Concerns about data security and privacy in the metaverse could hinder its adoption, especially when dealing with sensitive project information."

Resistance to Change: Participants acknowledged potential resistance to change from educators and students accustomed to traditional teaching methods.

> "Resistance to change among educators and students who are accustomed to traditional teaching methods may slow down the transition to a metaverse environment."

Technical and Logistical Challenges: Participants highlighted the need for user-friendly platforms, ongoing technical support, and addressing potential technical issues that could disrupt learning.

> "Ensuring that the metaverse platforms are user-friendly and accessible to individuals with varying levels of technological proficiency is a significant challenge."

> "The need for ongoing technical support and maintenance to address issues such as software updates and potential glitches can be a logistical challenge."

> "The potential for technical issues, such as connectivity issues or software glitches, may disrupt the continuity of lessons and impact the learning experience."

Pedagogical Considerations: Participants raised concerns about adapting assessment methods for virtual settings, managing the learning curve for both educators and students, and overcoming the perception that virtual experiences lack the richness of real-world interactions.

> "Adapting assessment methods to evaluate students' performance in a virtual setting presents a challenge, especially for traditional testing approaches."

> "Managing the learning curve for both educators and students in adapting to the new technology can be time-consuming and may affect the pace of learning."

> "Overcoming the perception that virtual experiences lack the richness and depth of real-world interactions may be a psychological hurdle for some learners."

> "Striking a balance between the advantages of immersive experiences and potential sensory overload in the metaverse is a design consideration."

Ethical, Legal, and Accreditation Issues: Participants highlighted concerns about distractions, ethical behavior within the metaverse, alignment with accreditation standards, copyright and intellectual property issues, and addressing potential cultural barriers.

> "Addressing potential distractions within the metaverse, such as unrelated virtual elements, could impact the focus and effectiveness of learning experiences."

> "Establishing guidelines and best practices for ethical behavior within the metaverse to maintain professionalism and integrity is a challenge."

> "Ensuring that the Metaverse environments align with accreditation standards and industry requirements is crucial for the recognition of educational programs."

> "Navigating copyright and intellectual property issues in a virtual space, especially when using real-world project scenarios, poses legal challenges."

> "Addressing potential cultural barriers that may affect the acceptance and effectiveness of the metaverse in diverse educational settings."

These findings provide a comprehensive overview of the perceived potential and challenges associated with integrating the metaverse into project management education, offering valuable insights for educators, institutions, and policymakers.

5. Discussion

This study explored the potential of the metaverse in project management education through qualitative research involving interviews with project management professionals. The findings reveal a complex picture, highlighting both significant opportunities and considerable challenges associated with metaverse integration.

5.1. Enhancing practical experience and bridging the theory-practice gap

A key finding centers on the metaverse's potential to enhance practical experience. Participants consistently emphasized its capacity for immersive learning through simulations, virtual internships, and realistic project scenarios. This resonates with existing literature highlighting the limitations of traditional, theory-heavy approaches in project management education. The metaverse offers a dynamic, risk-free environment where students can apply theoretical knowledge, experiment with different strategies, and experience the consequences of their decisions in a safe setting. This addresses a crucial gap in current education by providing hands-on experience that better prepares students for real-world project complexities. This immersive approach aligns with findings from Jaccard et al. (2022) and Fernández-Sánchez et al. (2022), who highlight the use of VR and metaverse technologies in training scenarios within various industries.

5.2. Challenges and Obstacles to Metaverse Adoption

The adoption of metaverse technologies in education, while promising, faces several significant challenges that must be addressed for successful implementation. One of the primary barriers is financial and infrastructural, as the high initial investment in hardware, software, and training, combined with unequal access to technology and internet connectivity, can hinder institutions with limited resources. Integration and compatibility issues also arise, as incorporating the metaverse into existing curricula requires substantial course redesign and pedagogical adjustments, made more complex by the lack of standardization across metaverse platforms. Security and privacy concerns, particularly regarding the protection of sensitive project information in virtual environments, further complicate the adoption process, necessitating robust security protocols and data governance policies. Resistance to change from educators and students accustomed to traditional learning methods poses an additional obstacle, highlighting the need for effective change management strategies. Moreover, technical and logistical challenges, such as ensuring user-friendly platforms, providing ongoing technical support, and managing technical glitches, are critical to maintaining a smooth learning experience. From a pedagogical perspective, adapting assessment methods, managing the learning curve for users, and ensuring the richness of virtual experiences compared to real-world interactions are significant concerns. Finally, ethical, legal, and accreditation issues, including concerns about ethical behavior in virtual environments, alignment with accreditation standards, copyright issues, and cultural barriers, require careful consideration. Addressing these challenges through careful planning and strategic implementation is essential for fully realizing the potential of the metaverse in education and ensuring equitable access for all students.

5.3. Recognition of Innovation and Transformative Potential

Despite the challenges, participants overwhelmingly expressed optimism about the metaverse's transformative potential in project management education. They recognized its groundbreaking nature in certifying student success through practical learning and hands-on approaches. The use of simulations for realistic evaluations was seen as a crucial advantage. This aligns with the broader trend of digital transformation in education, as highlighted by Fernández-Sánchez et al. (2022) and Jaccard et al. (2022), who emphasize the importance of integrating digital technologies and serious games into curricula.

Participants viewed the metaverse as a pivotal force in the future of project management, with its potential to revolutionize collaboration and learning, enhance practical skills, catalyze innovation and adaptability, facilitate global collaboration and continuous improvement, and provide a dynamic learning platform. This visionary perspective suggests a strong belief in the metaverse's capacity to redefine project management training and prepare students for the challenges of a rapidly evolving industry. The emphasis on realism, practical skill development, and adaptability aligns with the demands of the 4IR, as highlighted by Schwab (2017), who emphasizes the need for educational reforms to prepare the workforce for a future defined by complex technologies.

6. Practical implications

This study's findings, combined with existing project management theory, offer several practical implications for integrating the metaverse into project management education. The metaverse's immersive and interactive nature provides opportunities to enhance various aspects of learning and skill development:

6.1. Enhanced learning and skill development

The metaverse presents a novel paradigm for project management pedagogy, offering a transformative potential for enhanced learning and skill development. By leveraging immersive and risk-free simulated environments, the metaverse facilitates the application of theoretical concepts to authentic, real-world scenarios. This experiential learning approach, encompassing project planning, resource allocation, risk mitigation, and stakeholder engagement, cultivates practical skills and directly addresses the documented need for increased real-world application emphasized by learners. Furthermore, the integration of AI-powered collaborative tools within the metaverse significantly augments teamwork, communication, and workflow efficiency through real-time support, asynchronous collaboration, and streamlined processes. The advent of metaverse-based virtual internships provides invaluable industry exposure, enabling students to apply project management principles within interactive, professional-like contexts. This addresses the identified gap between academic learning and practical industry experience. Finally, the utilization of virtual reality (VR) technology within the metaverse enhances spatial comprehension and fosters a deeper understanding of real-world project environments, thereby bridging the gap between theory and practice and solidifying student preparedness for professional challenges.

6.2. Improving educational processes

The metaverse, through its immersive environment, offers significant potential for enhancing educational processes. Automated grading and feedback mechanisms, facilitated by advanced analytics and AI algorithms, can provide students with real-time performance analysis and visually engaging feedback, thereby optimizing the assessment process. Furthermore, AI-powered continuous monitoring and predictive analytics can identify struggling students early on, enabling timely interventions and personalized support. Additionally, the metaverse can host adaptive learning platforms that provide real-time personalization, flexible learning paths, and rich multimodal experiences, catering to diverse learning styles and promoting student engagement. Finally, the integration of virtual assistants within the metaverse provides 24/7 global support, personalized assistance, and dynamic integration of multimodal elements, enhancing student engagement and understanding.

6.3. Application to project management knowledge areas

The metaverse offers innovative applications across various project management knowledge areas, enhancing learning and practical experience. In project charter development, it allows for the simulation of collaborative creation and approval processes in a virtual environment, enabling real-time discussions and decision-making. For project management plans, it facilitates dynamic, interactive planning sessions where participants can collaboratively build and refine strategies. In scope, schedule, and cost management, the metaverse provides a visual platform for defining scope, developing schedules, and controlling costs, supporting collaborative work on work breakdown structures and financial oversight. Quality management is enhanced through virtual simulations that allow participants to identify and address quality issues. Resource management benefits from immersive simulations that focus on resource planning, team development, and control, providing insights into resource allocation and team dynamics. Communication management is improved by simulating real-world communication scenarios, enabling participants to practice stakeholder engagement, while AI integration can monitor communication effectiveness. In risk management, the metaverse offers a platform for identifying, analyzing, and responding to risks in a virtual setting. It also enhances procurement management by simulating procurement processes, offering participants a complete experience of the procurement lifecycle. Lastly, stakeholder management is supported through a virtual environment for stakeholder identification, analysis, and strategy execution, fostering a dynamic and immersive approach to managing stakeholder relationships.

6.4. Addressing practical challenges

The practical implications discussed above must be implemented with careful consideration of the challenges identified in the study. Addressing financial and infrastructure hurdles, integration and compatibility issues, security and privacy concerns, resistance to change, technical and logistical challenges, pedagogical considerations, and ethical, legal, and accreditation issues is crucial for successful metaverse integration. Pilot programs, phased implementation, and ongoing evaluation can help mitigate these challenges and maximize the benefits of the metaverse in project management education.

By implementing these practical applications and addressing the associated challenges, educators can leverage the metaverse to create more engaging, effective, and relevant project management learning experiences that prepare students for the demands of the 4IR.

7. Conclusion

This study investigates the transformative potential of the metaverse within the context of project management education. It meticulously examines both the advantages and the critical challenges that must be carefully considered for successful implementation. The metaverse emerges as a dynamic platform with the capacity to significantly enhance practical learning experiences (Zhang, 2023). Despite the ongoing challenge of aligning project management curricula with the rapidly evolving demands of the professional landscape, the metaverse, as an emerging digital frontier, possesses the transformative potential to reshape the traditional educational paradigm by effectively transforming the world into a virtual global school. (Kaddoura & Al Husseiny, 2023). By offering immersive simulations, virtual internships, and authentic real-world project scenarios, the metaverse provides a unique environment for students to apply theoretical knowledge and develop essential project management competencies. These critical competencies include leadership, communication, resource management, critical thinking, and problem-solving, all of which are crucial for successfully navigating the complexities of the Fourth Industrial Revolution (Rotatori et al., 2021).

The evolving technology underpinning the metaverse, including VR headsets, haptic gloves, AR, and Extended Reality (XR), enables users to fully immerse themselves in interactive experiences, prompting organizations to seriously consider its integration into existing business models (Dwivedi et al., 2022). The growing popularity of the metaverse across diverse domains further demonstrates its efficacy and versatility, offering immersive and interactive learning experiences within the realm of project management education (Jagatheesaperumal et al., 2022).

The utilization of the metaverse in project management education emerges as a transformative and promising avenue, supported by a growing body of scholarly perspectives and empirical evidence. Recent research strongly suggests that the metaverse can serve as a novel educational environment and an innovative pedagogical tool, effectively combining virtual and real-world educational settings (Chen, 2022; Hare & Tang, 2022). Equipped with wearable devices, learners can seamlessly enter immersive educational environments through the use of personalized digital identities, engaging in real-time interactions via avatars, or through the utilization of virtual learning resources. This hands-on approach provides students with the invaluable opportunity to engage with authentic and dynamic project management situations within a realistic virtual environment, thereby significantly enriching their comprehension and enhancing the development of critical competencies (Long, 2019).

The research questions guiding this study were comprehensively addressed through an analysis of the metaverse's role within the educational domain of project management. The findings demonstrate that the metaverse has the potential to enhance student engagement and learning outcomes. By creating immersive, simulation-based environments, it facilitates the application of theoretical concepts to authentic, real-world scenarios, fostering deeper understanding and improved knowledge retention. Furthermore, this study highlights the substantial benefits of metaverse technologies within the training context. These benefits include the facilitation of global collaboration, enabling students and instructors to connect and interact across geographical boundaries. The provision of real-time feedback mechanisms allows for immediate assessment and guidance, accelerating the learning process. Additionally, the metaverse develops practical skills through hands-on experiences in virtual environments, preparing students for the demands of modern project management roles. However, several critical challenges must be proactively addressed to ensure the successful and widespread adoption of metaverse-based educational initiatives. These challenges include:

- **Financial Constraints:** The initial investment in developing and maintaining metaverse platforms, acquiring necessary hardware (VR/AR devices), and providing ongoing technical support can be substantial for educational institutions.
- **Integration Complexities:** Integrating metaverse technologies into existing curricula and pedagogical approaches requires careful planning, faculty training, and ongoing evaluation to ensure effective learning outcomes.
- **Technological Limitations:** Issues such as limited accessibility to high-speed internet, compatibility issues with different devices, and potential for technical problems can disrupt the functioning of metaverse-based learning experiences.
- **Ethical Considerations:** Concerns related to data privacy, user safety, and the potential for the digital divide must be carefully addressed to ensure an equitable and inclusive learning environment for all students.

Despite these challenges, the metaverse has the potential to revolutionize project management education. By proactively addressing these critical issues through strategic implementation, continuous evaluation, and ongoing refinement, educators can effectively leverage the metaverse to create more effective, engaging, and relevant educational experiences.

This study explored the potential of the metaverse within project management education through a qualitative lens, employing thematic analysis based on Braun and Clarke's (2006) framework and informed by Gioia and Chittipeddi's (1991) sensemaking/sense giving perspective. This methodological approach facilitated an in-depth examination of how project management professionals not only identify existing challenges and propose solutions but also actively construct meaning around the concept of metaverse integration.

The findings reveal a dynamic interplay between these processes of sensemaking and sense giving. Participants engaged in sensemaking by diagnosing current shortcomings in project management education, including deficiencies in standardized curricula, limited practical application and soft skills development, and restricted industry exposure. Subsequently, they engaged in sense giving by proposing potential solutions, such as emphasizing experiential learning, fostering stronger links with industry and integrating relevant technologies, and prioritizing continuous professional development. Critically, participants also engaged in sensemaking regarding the metaverse itself. They interpreted its potential as a powerful instrument for addressing the identified educational gaps, envisioning immersive learning environments, enhanced opportunities for global collaboration, and expanded avenues for continuous professional development. However, this optimistic interpretation was tempered by a pragmatic assessment of potential challenges, including technological, financial, pedagogical, ethical, and security considerations. This highlights a key finding: the recognition of the metaverse's transformative potential is inextricably linked to a clear understanding of the obstacles that must be addressed for its successful and responsible implementation.

This dynamic between perceived benefits and anticipated challenges yields significant implications for practice. Educational institutions and educators should not view the metaverse as a simple technological solution but rather engage in a deliberate and strategic process of planning and implementation. This necessitates addressing the identified challenges through targeted investments in infrastructure, comprehensive pedagogical training for faculty, and the development of robust ethical guidelines and security protocols. Furthermore, fostering collaborative partnerships with industry experts and technology specialists is essential for creating relevant and effective metaverse-based learning experiences.

This study also suggests several avenues for future research. Further investigation is warranted to:

1. **Develop and rigorously evaluate specific metaverse-based learning interventions within project management education:** This involves designing and implementing pilot programs, collecting data on student outcomes, and analyzing the effectiveness of different metaverse applications in achieving specific learning objectives.
2. **Explore the long-term impact of metaverse integration on student learning outcomes and subsequent professional development:** Longitudinal studies are needed to track student progress, assess their career trajectories, and determine the long-term benefits of metaverse-based learning experiences.
3. **Investigate the broader ethical, social, and cultural implications of utilizing immersive technologies in educational contexts:** This includes examining issues such as equity of access, the potential for a digital divide, and the impact of immersive technologies on student well-being and social interactions.
4. **Develop and disseminate best practices for mitigating the identified challenges, including technological barriers, pedagogical considerations, and security concerns:** This involves sharing knowledge and resources among educators, developing guidelines and frameworks for best practices, and fostering a community of practice around the use of the metaverse in education.

By understanding the nuanced processes of sensemaking and sense giving inherent in the perception and implementation of the metaverse, educators and researchers can collaborate to responsibly harness its transformative potential, ultimately contributing to a more effective, engaging, and equitable future for project management education.

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Appendix A. Semi-structured interview questions:

- What are the problems you observe in global Project Management education?
- How do you think current project management education can be improved?
- Can Metaverse improve the quality of project management education?
- Do you think metaverse should be used in project management education? How?
- For what purposes can Metaverse be used in project management education? What opportunities do you think Metaverse has that the traditional method does not offer?
- How would you evaluate the obstacles to using the Metaverse environment in project management education?
- What do you think about using metaverse to measure and certify student success in project management education?
- How do you evaluate the Metaverse phenomenon in terms of the future of Project Management?

Biographical notes

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