Rere Āwhio

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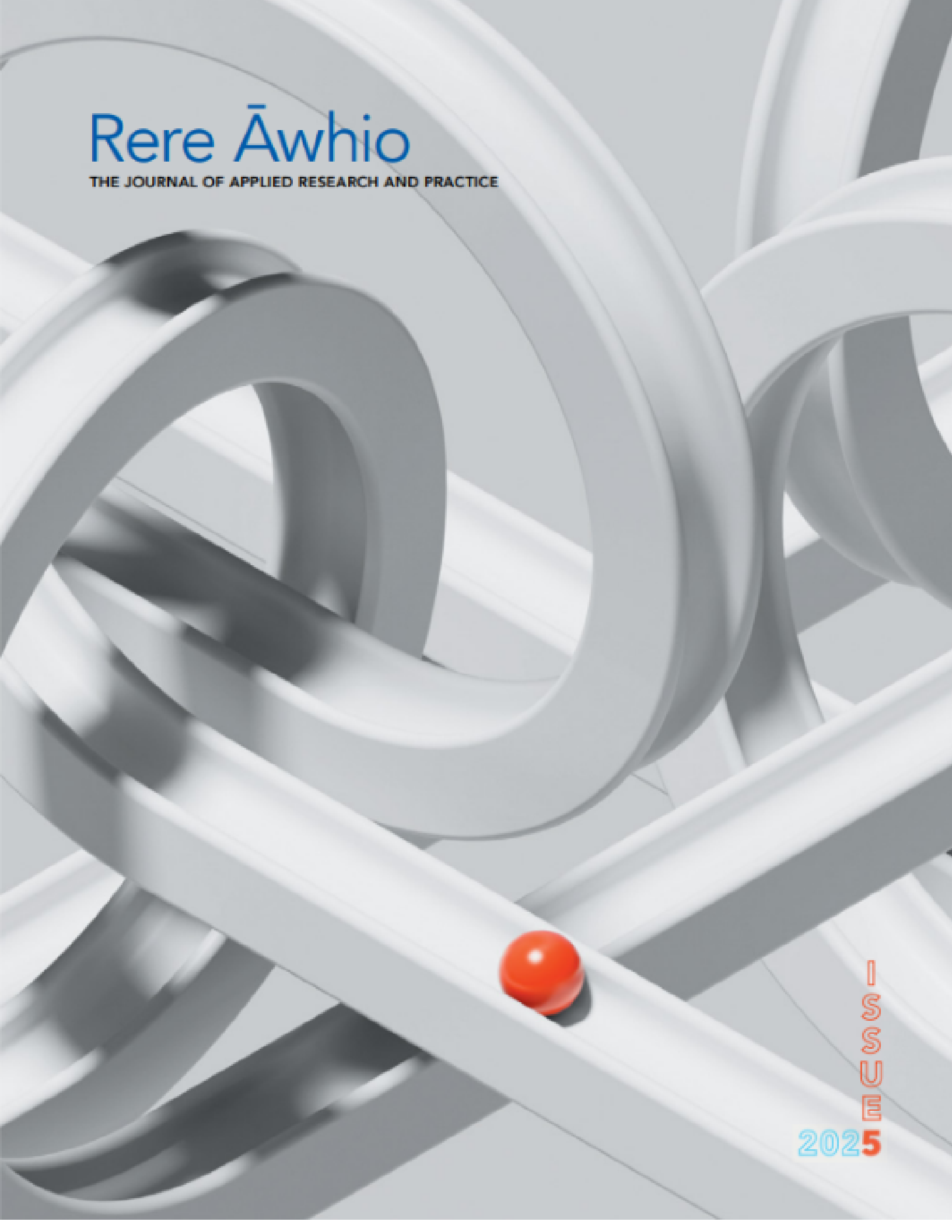

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Figures (images, diagrams, etc.) and tables should be inserted with full captions into the text to indicate where they would be placed and should also be sent separately (with copyright permissions attached where relevant). A LaTeX article template and full instructions are available on our website.

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ing peer review All final decisions concerning publications of submission will reside with the Editors. All material for standard issues will be published both in hard copy and online.

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Editorial

Innovation, Reflection, and Responsibility in a Transforming World

In this issue of Rere Ãwhio, we explore how technology-led change is being shaped, often decisively, by the human capabilities, governance choices, and ethical commitments that sit beneath the tools themselves.

A recurring impression across this issue is that innovation does not begin with novelty; it begins with readiness. Our study of Generative AI adoption in Australasian contact-centre environments makes this plain: the most commonly reported barriers are not abstract fears, but foundational constraints, data quality and availability, integration and infrastructure, together with cost and resourcing. Yet the findings also point to a more subtle challenge: stakeholders recognise governance priorities, while struggling to articulate the concrete mechanisms that would allow organisations to innovate safely and consistently.

If governance is one pillar, trust is another. In tourism and hospitality, AI chatbots now accompany customers throughout the journey, but technological efficiency alone does not secure loyalty, trust functions as the bridge between use and meaningful outcomes. The literature shows trust being built through functional reliability and information quality, but also through emotional and relational cues, and it is most fragile after service failures, where trust repair remains under-explored. That same trust question reappears in organisational GenAI deployment, where reliability concerns and accountability for mistakes shape the boundaries of adoption.

Across operational domains, the issue also returns repeatedly to the discipline of systems thinking. In manufacturing, resilience is treated as a measurable capability: data-driven analysis links stronger supplier collaboration and transportation efficiency to improved supply-chain resilience, while longer and more variable lead times diminish it. In construction, inefficiencies in documentation, decision-making, and rework have cascading effects on waste and project performance, made all the more pressing in Aotearoa New Zealand where construction and demolition waste is reported at approximately seven million tonnes annually. In healthcare supply chains, blockchain paired with data analytics is examined as a pathway toward safer traceability, while the authors remain clear-eyed about barriers such as implementation cost, staff capability, integration complexity, and legal uncertainty.

Leadership, in this issue, is not presented as charisma but as craft. Aleksandra (Sasha) Skakun's journey frames transformation as cultural shift rather than mere delivery, anchored in her "people, processes, and platforms" lens. Her reminder that "AI provides the insights; people make the decisions" reinforces a central argument across the issue: responsibility does not diminish as automation rises, it becomes more explicit. This aligns with our review of financial-sector governance, which argues that boards require stronger digital competence to oversee transformation effectively, especially given persistent DT failure rates and growing regulatory expectations.

Finally, as educators, we are invited not simply to react to GenAI, but to redesign for integrity. The Experiential Education Initiative launched at Auckland International Campus calls for authentic, employability-oriented learning activities and assessments that are "AI-safe" resisting misuse while tolerating legitimate AI use. Complementing this, the guidance on writing experiential assessment rubrics brings attention back to "criterion situations" and communities of practice: assessment should be grounded in what students can do in contexts that resemble real vocational work.

This issue of Rere Ãwhio is a testament to inquiry that not only advances knowledge but anchors it in purpose. May it inspire our readers to continue questioning, building, and leading with both head and heart.

The Editorial Team, Rere Ãwhio

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Literature Review

Are the Boards of Financial Firms in New Zealand Ready to Navigate the Digital Transformation Wave?

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ABSTRACT

Digital Transformation (DT) presents both opportunities and challenges for corporate governance. This literature review examines whether boards of directors in New Zealand's financial firms are equipped to navigate the wave of digital transformation. It synthesizes current research on the evolving concept of DT, the strategic outcomes and risks associated with DT initiatives, and the importance of board-level digital competence in guiding successful transformations. The review highlights that organizations with digitally savvy boards tend to achieve better performance and resilience, yet many boards, especially in New Zealand's financial sector, lack sufficient digital expertise. This gap raises concerns about oversight of technology-driven initiatives and risk management. By exploring theoretical frameworks (agency, stewardship, and upper echelons) and comparing international practices, the review underscores the need to integrate digital literacy and experience into board capabilities. We conclude that while awareness of DT's importance is growing, New Zealand boards remain in early stages of readiness. Strengthening board digital competence is essential for aligning digital initiatives with strategy, enhancing innovation, and mitigating emerging risks in the financial sector.

Keywords: Digital Transformation, *Corporate Governance*, *Board of Directors*, *Digital Expertise*, *Financial Sector*, *New Zealand*

INTRODUCTION

Corporate governance provides the framework through which boards direct organisational performance, manage risks, and safeguard stakeholder interests. Its scope has increasingly extended to strategic priorities such as technological disruption and digital risk management (Alabdullah et al., 2019; Kalia & Gill, 2023; Orazalin et al., 2025). Boards are now expected to guide digital strategies that ensure organisational resilience and competitiveness amid rapid technological change (Institute of Directors in New Zealand, 2024; Papagiannidis et al., 2025). In this study, Digital Transformation (DT) is understood as a strategic process of organisational renewal enabled by the integration of digital technologies to enhance operations, improve customer experiences, and develop new business models. This process is supported by board-level digital expertise to ensure effective governance and sustainable advantage (Awad & Martín-Rojas, 2024; Gong & Ribiere, 2021; Wahyudiono et al., 2024). Board competence in this context refers to the collective knowledge and capabilities of directors, including digital literacy and experience, which enable robust oversight, informed strategic decision-making, and effective risk governance (Bendig et al., 2023; Valentine & Stewart, 2015).

Despite the strategic importance of digital transformation, approximately 50% of DT initiatives fail to meet their objectives. This high failure rate highlights the critical need for effective governance and board-level digital competence (Benitez et al., 2022; Nwachukwu & Hieu, 2021). Competent boards can better oversee technology investments,

ensure cyber resilience, and align digital initiatives with strategic goals (Bendig et al., 2022; Firk et al., 2021). While roles such as Chief Information Officers (CIOs) and Chief Digital Officers (CDOs) have been studied extensively, empirical research on board-level governance of DT remains limited – particularly in New Zealand's financial sector (Bandodkar & Grover, 2022; The Reserve Bank of New Zealand & The Financial Markets Authority, 2023; Valentine & Stewart, 2015).

New Zealand provides a useful context for examining these governance issues because, as a small and globally connected economy, its financial firms face pressures from digitalisation and regulatory requirements similar to those in larger markets (Alabdullah et al., 2019; Kalia & Gill, 2023; Orazalin et al., 2025). Insights from this setting can inform international best practices by illustrating how boards in a highly regulated, small-market context develop digital oversight capabilities, enhance strategic agility, and build governance capacity. Accordingly, this study explores whether New Zealand's financial firm boards possess the digital expertise required to steer successful DT initiatives. The goal is to provide insights that can strengthen governance, digital leadership, and strategic decision-making in the face of accelerating digital transformation.

OVERVIEW OF DIGITAL TRANSFORMATION

Evolution of digital transformation

Despite increasing global attention, a universally accepted definition of "digital transformation" remains elusive, as its scope is context-dependent and continually evolving (Reis et al., 2018). Early research in the 1980s and 1990s focused on IT-enabled organisational change, exploring how emerging digital tools reshaped hierarchies, communication, and innovation (Bloomfield & Coombs, 1992; Drucker, 1988; Johnston & Vitale, 1988). Although the term digital transformation was not yet used, the idea of "IT-enabled business transformation" emerged during this period, highlighting the role of information technology in reshaping workflows and business processes (Chatfield & Bjørn-Andersen, 1997; El Sawy et al., 1999). Additionally, management initiatives such as Business Process Reengineering (BPR) and Enterprise Resource Planning (ERP) aimed to enhance efficiency and reduce costs through automation of repetitive, rule-based activities (Keller, 1993; Vidgen et al., 1994).

In the 2000s, DT gained prominence, though it was often conflated with related concepts like digitisation and digitalisation. Early conceptualisations in this decade emphasized process efficiency, operational optimisation, and supply chain improvements as key outcomes of digital initiatives (Bowersox et al., 2005; Brynjolfsson & Hitt, 2000). By the 2010s, DT was recognised as a strategic, evolutionary process that reshapes business models, organisational structures, and stakeholder relationships (Goran et al., 2017; Vial, 2019). Definitions of DT expanded to reflect broader strategic shifts: firms were leveraging digital technologies not only for incremental efficiency gains but to fundamentally transform operations and stakeholder interactions. In other words, digital transformation became established as a strategic imperative for competitive advantage (Frank et al., 2019; Gong & Ribiere, 2021).

Table 1 summarises the historical evolution of DT definitions, highlighting the shift from operationally focused views in early decades toward more strategic and holistic perspectives in recent years.

Table 1: Historical Overview of Digital Transformation Definitions

Time Period	Selected Definitions of Digital Transformation	Source
1990s	Digitisation of information is reported to enable a parallel 'marketspace', a virtual, information-defined environment that reshapes competition, value creation, and firms' business models alongside physical marketplaces." The broad adoption of digital technologies across information, communications, and media has redefined commerce, creating networks that restructure work, organisations, and market interactions into a "digital economy." Business Process Reengineering (BPR) is the process of re-evaluating and redesigning core business workflows to enhance efficiency and quality, mainly by automating repetitive, rule-based activities. Enterprise Resource Planning (ERP) refers to advanced systems designed to integrate the functions of different departments into a unified enterprise-wide process through modern information technologies.	Rayport & Sviokla (1994), Tapscott (1996), Vidgen et al. (1994), and Keller (1993).
2000s	Digital technologies serve to innovate or adjust business processes and models, as well as to assist in reshaping organisational structures, resource allocation, and stakeholder interactions. Reinventing business processes to enable digital operations and strengthen relationships across the supply chain.	Brynjolfsson & Hitt (2000) and Bowersox et al. (2005).
2010s	DT is the use of technology to drive substantial improvements in organisational performance and scope. Executives utilise advances such as analytics, mobility, social platforms, and smart devices to reshape customer engagement, internal processes, and value delivery. DT is the comprehensive reshaping of businesses, underpinned by internet technologies and extending its influence across society at large. DT is the integration of businesses, customers, and other stakeholders across the entire value chain, enabled by the adoption of emerging technologies. DT is the process of upgrading organisations by leveraging combinations of information, computing, communication, and connectivity technologies to bring about significant shifts in their attributes.	Westerman et al. (2011), PWC (2013), Schallmo & Williams (2018), and Vial (2019).
2020s	DT is a strategic renewal process, fuelled by cognitive technologies that significantly boost innovation and reshape how value is created. DT involves improving an entity by driving major modifications in its properties using a combination of configuration, computing, communications, and connectivity technologies. DT is a transformative process that fundamentally reshapes organisations through the innovative application of digital technologies, combined with the strategic leverage of resources and capabilities. *(Cognitive technologies include tools such as Artificial Intelligence (AI), Machine Learning, and the Internet of Things (IoT).)* DT entails adopting digital technologies across enterprises to optimise customer interactions, enhance core processes, and establish or refine business models.	Cranney et al. (2025), Wahyudiono et al. (2024), Gong & Ribiere (2021), Verhoef et al. (2021), and Awad & Martín-Rojas (2024).

Note: The sources illustrate the conceptual evolution of digital transformation from a focus on operational efficiency in early decades to strategic, holistic change in recent years.

Over time, digital transformation has clearly evolved from a set of operationally focused initiatives aimed at process automation and efficiency into a strategic, organisation-wide phenomenon reshaping business models, structures, and stakeholder interactions. Recent definitions emphasise advanced digital and cognitive technologies (e.g. AI, machine learning, IoT), highlighting the critical role of executives and boards in driving transformation and overcoming entrenched organisational mindsets (Awad & Martín-Rojas, 2024; Cranney et al., 2025; Wahyudiono et al., 2024).

Drawing on the range of definitions above; particularly Awad and Martín-Rojas (2024), Gong and Ribiere (2021), and Wahyudiono et al. (2024), this review defines digital transformation as a strategic organisational change process

enabled by innovative digital technologies. It is aimed at improving operational processes, enhancing customer experiences, and developing new or transformed business models, while leveraging key organisational resources and board-level digital expertise. Understanding this evolution of DT provides an important foundation for the governance focus of this study. It illustrates that boards must now possess the necessary digital capabilities to strategically guide DT initiatives, ensure alignment with organisational objectives, and manage the risks associated with transformation, particularly in New Zealand's financial sector context.

Outcomes and challenges of digital transformation

Although digital transformation offers significant strategic advantages, its desired outcomes are far from guaranteed. Various studies report failure rates for DT initiatives around 50%, even among well-resourced firms (de la Boutetière et al., 2018). When implemented effectively, DT can improve internal coordination, increase resource flexibility, and boost overall organisational performance (Lusch & Nambisan, 2015; Trantopoulos et al., 2017). It enables firms to explore new digital business models, foster innovation, and create value through interconnected ecosystems (Jacobides et al., 2018). Empirical evidence also suggests that digitally mature organisations financially outperform their peers, demonstrating higher profitability and market valuations (Valentine, 2016; Valentine & Stewart, 2015). Notably, firms with digitally savvy boards tend to achieve better financial outcomes – including higher return on assets, revenue growth, and profit margins, as investors and stakeholders place a premium on the strategic insight that digital expertise brings to decision-making (Filatotchev et al., 2025; Weill et al., 2019).

However, technology alone does not guarantee success in transformation. Organisations must integrate social and technical change elements, develop new skills and culture, adapt organisational structures, and continuously innovate business models to fully realise the benefits of DT (Filatotchev et al., 2025; Viscusi & Tucci, 2018). This underscores the critical role of the board: beyond passive oversight, directors must understand the scope and pace of digital disruption and provide active strategic guidance. Yet many boards lack confidence in their ability to make informed digital decisions (Bandodkar & Grover, 2022; Institute of Directors in New Zealand, 2024). By linking DT outcomes to board responsibilities, current research emphasizes the governance dimension of transformation. Board-level digital competence is increasingly seen as pivotal for steering digital initiatives, aligning them with long-term strategy, and mitigating the risks associated with digital disruption.

Digital transformation in the financial sector

The financial services industry exemplifies both the high stakes and opportunities of digital transformation. This sector faces pronounced DT challenges due to its combination of stringent risk management requirements and pressure to innovate. For instance, advanced analytics and AI have been deployed by banks to enhance fraud detection and cybersecurity: ANZ Group's use of AI/machine-learning tools helped prevent an estimated $20 million in fraud losses. Conversely, the risks of digitalisation were highlighted by the 2019 Capital One data breach, which exposed sensitive data of over 100 million customers (Khan et al., 2022). Thus, while technologies such as artificial intelligence, blockchain, and big data analytics are reshaping financial products and services, they are also introducing new vulnerabilities (Onyeje et al., 2024). According to the Financial Services Information Sharing and Analysis Center (FS-ISAC), cyberattacks against financial institutions worldwide increased by 80% in 2022 amid the shift to remote work during the COVID-19 pandemic. Key threats include phishing, malware, identity theft, and breaches of intellectual property (Lacombe & Jarboui, 2023). These trends underscore the urgency of effective data protection and cyber-risk governance in finance.

Governments and regulators have recognised the strategic importance of digital transformation in finance. In New Zealand, for example, the government established a Digital Executive Board (DEB) in 2022 to coordinate national digital strategy and capability-building efforts across sectors (Department of Internal Affairs, 2023). Similarly, financial regulators such as the Reserve Bank of New Zealand (RBNZ) and the Financial Markets Authority (FMA) have emphasized the need for strong board oversight and digital competence to manage technological risks while enabling innovation (The Reserve Bank of New Zealand & The Financial Markets Authority, 2023). Internationally, studies consistently find that banks and financial firms with digitally experienced board members exhibit better performance, greater strategic agility, and enhanced risk management (Filatotchev et al., 2025; Valentine & Stewart, 2015; Weill et al., 2019).

In summary, effective digital transformation in finance requires not only substantial technology investment but also competent governance and strategic oversight. Boards with digital expertise are central to this effort: they help ensure that digital initiatives align with the firm's objectives, that cyber and operational risks are proactively mitigated, and that innovation is pursued responsibly (Bandodkar & Grover, 2022; Institute of Directors in New Zealand, 2024). These observations provide a foundation for examining New Zealand financial firms' readiness to navigate the DT wave. In particular, they highlight the importance of assessing whether boards have the necessary digital competencies to govern transformation initiatives effectively.

DIGITAL COMPETENCE IN CORPORATE GOVERNANCE AND DIGITAL STRATEGY IMPLEMENTATION

Definitions and pathways to digital expertise

Board-level digital expertise plays a pivotal role in shaping the outcomes of digital transformation. Directors with relevant technological knowledge and experience are better equipped to oversee technology-driven change and to ensure that digital initiatives are aligned with organisational strategy (Bendig et al., 2023; Ceipek et al., 2021; Kahveci, 2025). While the roles of top management (such as CIOs and CDOs) in driving digital projects have been widely examined, far less attention has been given to the role of the board in providing strategic oversight for DT (Bandodkar & Grover, 2022; Turel et al., 2019). This gap in the literature is now starting to be addressed as researchers acknowledge that boards, not just executive teams, must cultivate digital savvy.

Directors may acquire digital expertise through several avenues. Common pathways include formal education or certification in information technology fields, prior executive experience in technology-centric roles (e.g. serving as a Chief Technology Officer), or leadership experience within highly digitised industries (Bandodkar & Grover, 2022; Filatotchev et al., 2025). Such expertise enables board members to move beyond a narrow, compliance-oriented view of digital risk. Instead, digitally savvy directors can critically evaluate technology investments, anticipate emerging technological threats, and guide organisation-wide change processes. In this way, digital competence at the board level strengthens overall governance effectiveness by ensuring that digital initiatives are integrated into long-term strategic decision-making rather than treated as peripheral IT projects.

Theoretical frameworks influencing board effectiveness

To understand how digital expertise contributes to board effectiveness, scholars have applied several theoretical lenses. Agency theory positions the board of directors primarily as a monitoring mechanism to mitigate conflicts of interest between shareholders (principals) and management (agents), particularly in contexts of information asymmetry (Fama & Jensen, 1983; Gwala & Mashau, 2023). In the context of digital transformation, asymmetry between

board and management can be pronounced, as managers often hold deeper technical knowledge of the firm's digital initiatives (Benaroch & Fink, 2021). Directors with digital expertise can help narrow this knowledge gap, asking the right questions and challenging management assumptions, thereby strengthening oversight and reducing agency risks (Benaroch & Fink, 2021; Caluwe et al., 2024).

While agency theory emphasizes control and monitoring, stewardship theory offers a complementary perspective by highlighting the board's advisory and collaborative role. Under stewardship theory, directors and executives are viewed as partners working toward shared organisational goals (Davis et al., 1997; Obermann et al., 2020). From this perspective, digitally competent directors provide value by aligning DT initiatives with the firm's strategy, offering informed guidance to management, and fostering trust and open dialogue around technology adoption (Vincent et al., 2018). Their expertise enables them to act as stewards of digital innovation, helping management teams navigate complex decisions and avoid pitfalls.

Complementing both these views, upper echelons theory suggests that organisational outcomes are partly a reflection of its top leaders' characteristics and experiences (Hambrick & Mason, 1984). Applying this lens, directors with significant digital backgrounds bring distinctive cognitive frames and perspectives to the boardroom. They are more likely to recognise technological opportunities and threats, champion innovative investments, and advocate for the organisational changes needed to leverage new technologies (Firk et al., 2022). In essence, a board's collective expertise can shape the firm's strategic direction and adaptability.

Taken together, these theoretical perspectives provide a multidimensional understanding of why board-level digital competence matters. Agency theory underscores the oversight benefits of having tech-savvy directors (better monitoring and risk mitigation), stewardship theory highlights the collaborative strategic guidance they offer, and upper echelons theory points to the vision and innovation orientation they instill. Integrating these insights, this study situates digitally competent boards as central to both effective governance and the successful implementation of digital transformation initiatives.

Challenges in board-level governance for digital strategy

Even when a board includes some technology-savvy members, translating that expertise into effective boardroom practice can be challenging. Boards with limited overall digital literacy often struggle to anticipate technological shifts, which in turn hinders organisational responsiveness and innovation (Filatotchev et al., 2025). Moreover, evidence suggests that having a single "digital expert" on the board is rarely sufficient. Truly embedding digital thinking into governance may require three or more digitally competent directors to ensure that technology considerations consistently inform board discussions and decisions (Drechsler et al., 2020). In other words, digital expertise should ideally be widespread among board members, not isolated to one individual, to influence the board's culture and agenda.

In New Zealand, this challenge is particularly evident. A recent director survey found that fewer than one-third of NZ directors believe their board possesses adequate digital capability, reflecting a persistent "IT confidence gap" in boardrooms (Institute of Directors in New Zealand, 2024). Regulatory bodies such as the FMA and RBNZ have stressed the importance of board awareness of digital risks and oversight of DT initiatives, though there is currently no explicit mandate in New Zealand requiring boards to have directors with technology expertise (FMA, 2025; The Reserve Bank of New Zealand & The Financial Markets Authority, 2023). Boards that lack sufficient digital literacy risk not only making poor strategic choices but also attracting heightened scrutiny from regulators and stakeholders concerned about governance of technology and cyber risks.

Comparatively, New Zealand boards appear less prepared to integrate digital expertise systematically than those in some other economies. In Australia, for example, the Australian Prudential Regulation Authority's standard CPS 510 has raised expectations for boards to demonstrate robust governance in the face of digital disruption and cyber risk (Australian Prudential Regulation Authority, 2019). Singapore offers another benchmark: leadership commitment to digital transformation there is notably strong, with a majority of corporate leaders actively role-modeling digital behaviors that encourage organisational commitment to digital initiatives. In one study, 67% of Singaporean leaders were rated as actively encouraging commitment to a digital future, 68% were motivating employees to achieve DT objectives, and 60% were creating positive employee experiences with digital tools (Chandrasekar & Mallis, 2025). Such statistics indicate a high level of engagement from the top in driving digital change.

Earlier studies of IT governance in New Zealand (e.g. (Valentine, 2016; Valentine & Stewart, 2015) provided valuable foundations for understanding board-level digital leadership, but they largely predate contemporary challenges such as artificial intelligence, cloud computing, and sophisticated cybersecurity threats. Recent evidence suggests that although boards are increasingly aware of the strategic importance of technology, many still do not prioritise building their own digital capability or systematically integrating digital considerations into decision-making (Institute of Directors in New Zealand, 2024; Jose et al., 2025). This misalignment between recognising the importance of digital issues and taking concrete governance action remains a concern.

CONCLUSIONS

In summary, the strategic integration of digital expertise into New Zealand's boardrooms remains in its early stages. While national digital strategies and overall awareness of technology's importance are growing, significant gaps persist between the perceived importance of digital transformation and actual governance capacity at the board level. This literature review has highlighted that boards with higher digital competence tend to better navigate digital disruption, leading to stronger organisational performance and innovation. However, many boards in New Zealand's financial sector may not yet have the requisite skills and confidence to effectively oversee and guide digital transformation initiatives.

The question posed: Are the boards of financial firms in New Zealand ready to navigate the digital transformation wave? can be answered only partially at this stage. The evidence suggests that some progress has been made in acknowledging digital transformation as a board-level priority, but readiness levels are uneven. Boards that proactively build digital literacy and invite technology-experienced directors are likely to be more prepared to leverage new technologies and guard against associated risks. By contrast, boards that remain digitally complacent risk impairing their firm's strategic agility and resilience in a rapidly changing environment.

Strengthening board-level digital competence emerges as a clear imperative. This includes targeted director training, recruiting or co-opting directors with technology backgrounds, and fostering a board culture that values continuous learning about digital trends. Such steps would help ensure that New Zealand's financial firms are governed by leaders capable of steering digital transformation effectively. Future research could further examine the impact of specific governance interventions (such as board technology committees or advisory roles) on digital transformation success. Ultimately, preparing boards to ride the digital transformation wave will not only improve individual firm outcomes but also contribute to the stability and competitiveness of New Zealand's financial industry in the digital age.

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Literature Review

Friend, Guide, or Frustration? Understanding Trust in AI Chatbots for Tourism and Hospitality

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ABSTRACT

Artificial intelligence (AI)-based chatbots are increasingly deployed in the tourism and hospitality industry to support travellers and guests across the customer journey. Their adoption reflects the sector's broader digital transformation and the need for efficient and always-available service tools. However, in a field where experiences and relationships are central, technological efficiency alone does not guarantee customer satisfaction or loyalty. Trust functions as the critical bridge linking chatbot use to positive customer outcomes. Despite the rapid growth of chatbot applications, research on their role in shaping trust is limited and fragmented. Existing studies highlight functional benefits such as reliability and information accuracy; however, evidence is mixed on the emotional and cultural dimensions of trust. The aim of this study is to critically evaluate how AI-based chatbots influence customer trust in the tourism and hospitality industry and to identify underexplored areas for future research. To achieve this, a systematic literature review was conducted, and the findings were synthesised using thematic analysis. The review identifies three themes: (a) functional trust foundations, (b) emotional and relational mechanisms, and (c) trust erosion after service failures, while highlighting gaps in trust repair and non-user trust. The findings contribute to theory by advancing understanding of trust as both a functional and emotional construct in AI-mediated services. They also contribute to practice by encouraging tourism and hospitality providers to design chatbots that are not only efficient but also empathetic, human-like, and culturally sensitive, thereby reinforcing trust and sustaining long-term brand loyalty.

Keywords: Artificial intelligence, Chatbots, Customer trust, Tourism and hospitality, Systematic literature review

INTRODUCTION

The rapid digital transformation of the tourism and hospitality industry has reshaped how services are delivered and how customers engage with providers. The acceleration of automation to minimise physical contact during the COVID-19 pandemic, along with the rapid development of generative artificial intelligence (AI), has made AI-based chatbots an increasingly central part of customer interactions (Choi et al., 2022; Dogru et al., 2025). These tools now assist travellers across the entire journey from planning and booking to post-visit communication and feedback(Orden-Mejía et al., 2025; Zhang et al., 2025). For instance, major hotel chains such as Marriott use AI-driven chatbots to confirm bookings and handle check-in queries, while airlines like Singapore Airlines employ chatbots to provide flight updates and personalised travel assistance. Given the highly experiential and relational nature of tourism, trust is essential for customer adoption, loyalty, and satisfaction (Chen et al., 2022; Chi & Vu, 2023). However, there is still debate about whether AI chatbots strengthen or weaken customer confidence in the provided services (Nguyen et al., 2023; Wong et al., 2023). Understanding this issue is crucial for tourism operators who must balance efficiency with personal, emotionally sensitive, and culturally aware interactions.

Existing studies show that practical features such as ease of use, responsiveness, and the accuracy of information play an important role in customer trust and acceptance of chatbots (Lu et al., 2019; Pillai & Sivathanu, 2020) At the same time, researchers have begun to emphasise the social and emotional aspects of these interactions, including empathy, human-like qualities, and cultural fit (Folk et al., 2025; Nguyen et al., 2023; Pelau et al., 2021). Yet, when expectations are not met, such as when communication feels impersonal or support is not provided, customers may feel less inclined to rely on the service (Husnain et al., 2025; Scarpi, 2024). Another area that has received limited attention is how "non-users," such as observers or bystanders, form impressions of chatbots and whether these perceptions affect trust (Orden-Mejía et al., 2025; Wong et al., 2023). These areas highlight that while progress has been made, there is still much to learn about the different ways in which trust in AI chatbots develops in tourism contexts.

Considering these gaps and unanswered questions, a systematic review of the literature offers a timely and valuable way forward. By taking a comprehensive view of how AI chatbots are used in tourism and hospitality, this study provides a rigorous assessment of current knowledge while also identifying areas that need further exploration. In doing so, this study aims to address the following research questions:

1. What is the current state of knowledge on the role of AI chatbots in shaping customer trust in tourism and hospitality?
2. What are the main directions for future research on AI and customer trust in tourism?

In answering these two questions, the study makes three contributions. First, it brings evidence from peer-reviewed journal articles to provide a comprehensive overview of how AI chatbots affect trust in tourism services. Second, it develops a broader understanding of trust by drawing attention to areas that have not been widely explored, such as how trust is restored after challenges and how non-user trust is formed. Third, it offers practical suggestions for managers and designers by highlighting strategies that combine reliability with emotional intelligence and cultural awareness. These contributions offer both a stronger theoretical base and valuable guidance for applying AI chatbots in the tourism and hospitality industry.

METHODOLOGY

A systematic literature review (SLR) approach was adopted to ensure rigour, transparency, and replicability in synthesising knowledge on the role of AI chatbots in shaping customer trust in tourism and hospitality (Snyder, 2019). An SLR is particularly well-suited for this study because the field of AI in tourism is still emerging, highly fragmented, and characterised by rapid technological and conceptual developments. As prior reviews have shown in related disciplines (Budhwar et al., 2022; Xiao & Watson, 2019), systematic reviews provide a structured way to map existing knowledge, evaluate patterns and inconsistencies, and identify key gaps that can inform future research. Unlike traditional narrative reviews, which may be selective or interpretive, the SLR method follows explicit steps in identifying, screening, and analysing studies, thereby reducing bias and improving the reliability of conclusions. This approach is therefore appropriate for addressing the research questions of this study, which seek both to consolidate what is known and to highlight future directions.

Selection of articles and qualitative assessment

The review concentrated on peer-reviewed journal articles published between 2018 and 2025, a period that reflects the growing adoption of AI-powered chatbots in tourism and hospitality. To ensure coverage across disciplines, three

major databases were searched: Business Source Complete, Taylor & Francis Online, and ProQuest. These sources were selected because they provide high-quality access to journals in tourism and hospitality management while also capturing relevant contributions from marketing, information systems, and technology studies. The search strategy employed a set of keywords, including AI chatbot(s), tourism/hospitality, trust, and human–machine interaction. Additional searches were run through platforms such as Google Scholar to ensure comprehensiveness. Studies were included if they met three criteria: (a) they were peer-reviewed empirical articles published between 2018 and 2025; (b) they focused on tourism, hospitality, or related travel services (e.g., OTAs, hotels, destination chatbots, service robots, or pandemic-related health chatbots with direct travel relevance); and (c) they explicitly examined trust or related constructs such as empathy, human-like qualities, reliability, or interaction quality. The initial search identified 78 papers, of which 25 were retained after full-text screening.

The final pool of 25 studies was considered sufficient and appropriate for two main reasons. First, a substantial proportion of the articles were published in well-regarded journals recognised in the Australian Business Deans Council (ABDC) Journal Quality List, including several A*/A-ranked journals (see Table 1). While not all studies were from top-ranked outlets, the overall distribution indicates that the evidence base largely reflects credible and peer-reviewed scholarship. Second, the selection captured a broad geographical and sectoral scope, covering online travel agencies, hotels, destination management, service robots, and pandemic-related health chatbots linked to travel (e.g. (Cai et al., 2022; Orden-Mejía et al., 2025). This range ensures that the review draws on diverse contexts within tourism and hospitality to enhance the representativeness of the findings.

Table 1: Summary of Journal Ranking

Journal / Outlet	**ABDC 2022**	**Quartile (SJR 2024)**	**Included**
Tourism Management	A*	Q1	3
International Journal of Hospitality & Management	A*	Q1	3
International Journal of Contemporary Hospitality Management	A	Q1	2
Journal of Cross-Cultural Psychology	A	Q1	1
Journal of Hospitality & Tourism Research	A	Q1	1
Journal of Hospitality Marketing & Management	A	Q1	1
Journal of Hospitality and Tourism Management	A	Q1	1
Journal of Travel Research	A*	Q1	1
Journal of Travel & Tourism Marketing	A	Q1	1
The International Journal of Human Resource Management	A	Q1	1
Electronic Markets	A	Q1	1
Journal of Services Marketing	A	Q1	1
Computers in Human Behavior	A	Q1	1
Consumer Behavior in Tourism and Hospitality	B	Q2	1
The Service Industries Journal	B	Q1	1
Journal of Hospitality and Tourism Technology	B	Q1	1
Technology in Society	C	Q1	1
Future Generation Computer Systems	—	Q1	1
Frontiers in Psychology	—	Q2	1
PLOS ONE	—	Q1	1
Cyberpsychology, Behavior, and Social Networking	—	Q1	1

Notes. ABDC = ABDC Journal Quality List (2022; latest public release). Quartile uses SCImago SJR 2024 for consistency across disciplines. "—" = not listed / not applicable.

Data Analysis

To systematically organise the findings, a literature review matrix was used to record the objectives, contexts, methods, samples, and key findings of each study. The data were analysed using a thematic analysis approach (Braun & Clarke, 2006). To ensure consistency, the coding framework was iteratively verified and refined, enhancing the reliability of interpretation (Bazzoli & Probst, 2023). This systematic approach allowed the review to identify not only recurring findings but also contextual variations and boundary conditions across different studies.

RESULTS

The descriptive features of the 25 included studies are represented in Table 2 and provide an overview of the methodological research approaches, geographic concentration, and research focus. Table 3 illustrates the theme development process through an example of selective codes that informed the categorisation discussed in this section.

Table 2: Descriptive Characteristics of the Studies Included

No.	Author(s) & Year	Sample	Country	(Research) (design)	(Main research question(s)
1	Adam et al. (2021)	Online participants interacting with customer-service chatbots	Germany	Quantitative	How do verbal anthropomorphic design cues and the foot-in-the-door technique affect user compliance in customer-service chatbot interactions?
2	Dogru et al. (2025)	Hospitality and tourism experts	International	Qualitative	What is the role of generative artificial intelligence (GAI) and postulates expert opinion on the implications of GAI for hospitality and tourism stakeholders
3	Belanche et al. (2020)	N/A	International	Qualitative	What are the key dimensions and factors for service managers to consider when implementing service robots?
4	Budhwar et al (2022)	N/A	International	Qualitative	What are the challenges and opportunities of AI for international HRM, and how does AI impact employee and organisational outcomes?
5	Bock et al. (2020)	N/A	International	Qualitative	How is artificial intelligence disrupting traditional service marketing practices and consumer experiences?
6	Cai et al. (2022)	Users of OTA chatbots	China	Mixed Methods	What are the perceived chatbot anthropomorphism cues and their effects on customers' chatbot usage intentions (UIs) in the online travel agency context?
7	Chen et al. (2022)	Customers of home-sharing platforms	Australia	Quantitative	How do customer trust and artificial intelligence influence customer engagement and loyalty in the home-sharing industry?

No.	Author(s) & Year	Sample	Country	(Research) (design)	(Main research question(s)
8	Choi et al. (2022)	Customers of cafes	Global (online-based)	Quantitative	What effects do human vs. robot baristas have on perceived safety and visit intention during COVID-19?
9	Ciechanowski et al. (2019)	Chatbot users	Poland	Mixed Methods	How do different chatbot interfaces influence the uncanny valley effect and users' affective responses?
10	de Kervenoael et al. (2020)	Visitors in hospitality services	Singapore	Mixed Methods	What factors influence visitors' intentions to use social robots in hospitality, focusing on perceived value, empathy, and information sharing?
11	Husnain et al. (2025)	Chatbot users	China	Mixed Methods	How do chatbot negative experiences shape brand hate and outcomes in hospitality and tourism?
12	Folk et al. (2025)	University students with East Asian and European cultural background	Canada	Quantitative	Do people from different cultural backgrounds differ in their attitudes toward social chatbots, and are these cultural differences mediated by the degree to which individuals anthropomorphise the chatbot?
13	Kasilingam et al. (2020)	Users of a custom e-commerce chatbot	India	Quantitative	What factors significantly influence attitude and intention to use smartphone chatbots for shopping?
14	Lu et al. (2019)	Hospitality industry consumers	USA	Quantitative	What are key dimensions characterizing consumers' willingness to integrate service robots?
15	Marghany et al. (2025)	UK hotel guests	UK	Quantitative	What factors contribute to robot acceptance by UK hotel guests?
16	Zhu et al. (2023)	Customers who had experienced the use of travel AI chatbots	China	Quantitative	How do consumers' perceptions of artificial intelligence (AI) chatbots influence individuals' cognitive and emotional states and their subsequent behavioural intentions vis-a-vis online travel agencies (OTAs)?
17	Nguyen et al. (2023)	413 hotel customers	Vietnam	Quantitative	What impacts do empathy response, anonymity, and customization of AI chatbots have on customer trust in the hotel industry?
18	Orden-Mejía et al. (2025)	Travelers using chatbots	International	Mixed Methods	How do AI-powered chatbots influence destination decision-making?

No.	Author(s) & Year	Sample	Country	(Research) (design)	(Main research question(s)
19	Pelau et al. (2021)	College students	Romania	Quantitative	What roles do interaction quality, empathy, and anthropomorphic characteristics play in customer acceptance of AI in services?
20	Pillai and Sivathanu (2020)	Travellers and travel agency managers	India	Mixed Methods	What factors influence the adoption intention and actual usage of AI-powered chatbots in tourism and hospitality?
21	Scarpi (2024)	Hotel customers	UK	Quantitative	How chatbot adoption affects psychological ownership and customer rebooking intention in tourism?
22	Shi et al. (2021)	Tourists with prior experience of AI technology	China	Quantitative	What factors influence travellers' trust and adoption intention toward AI recommendation systems?
23	Wong et al. (2023)	N/A	International	Qualitative	How do generative AI technologies like ChatGPT impact tourist decision-making in pre-trip, en-route, and post-trip stages?
24	Yu (2020)	YouTube reviews	International	Qualitative	What are public perceptions of humanlike robots employed as hotel frontline employees based on online reviews?
25	Zarouali et al. (2018)	Facebook users	International	Quantitative	What cognitive and affective factors influence consumers' attitudes and intentions to use and recommend chatbots on Facebook?

Table 3: Example of Theme Development and Selective Codes

Selective first-order themes	Second-order theme	Aggregate dimension
24/7 availability and rapid response time improve customer experience (20); prompt and readily accessible service reduces uncertainty in trip planning (22); real-time feedback creates assurance in service performance (14)	Performance reliability	Functional Trust Mechanisms
Perceived ease of use and usefulness enhance adoption intention (13, 18); intuitive interface design reduces user fatigue (6); fewer efforts improve interaction quality (9)	Usability and efficiency	Functional Trust Mechanisms
High quality, relevant, and timely information increases confidence in decisions (22); helpful and up-to-date chatbot answers (7); user context-adapted information increases perceived usefulness (17)	Informational value	Functional Trust Mechanisms
Destination-specific recommendations create satisfaction (18); chatbot recommendations that match intent make planning more successful (7); relevance of content to personal needs fosters loyalty (1)	Service alignment	Functional Trust Mechanisms
Regular, proper interaction establishes trust in the long term (14, 18); repeated action replenishes trust based on repeated use (14); repeated use generates user dependence (18)	Operational consistency	Functional Trust Mechanisms

Effects of functional capabilities of AI chatbots on trust

Customer trust in AI chatbots within tourism is closely shaped by their functional attributes, such as reliability, usability, and the accuracy of information they provide. Pillai and Sivathanu (2020) found that responsiveness, consistency, and 24/7 availability are strong predictors of chatbot adoption in hospitality settings. These qualities give users confidence that the system will perform well in service-critical situations. Similarly, Lu et al. (2019) identified that stable system performance builds structural trust, as reliability is an essential condition for users to accept service robots. In contrast, Kasilingam (2020) suggested that a simple interface and low cognitive effort foster trust by reducing user fatigue. In the same vein, Adam et al. (2021) found that AI chatbots that communicate clearly and respond accurately enhance users' willingness to comply with their suggestions. These studies demonstrated that functional dependability plays a vital role in trust formation, though they emphasise different aspects depending on the context. While Pillai and Sivathanu (2020) and Lu et al. (2019) focus on continuous performance in emotionally sensitive and time-pressured environments, Kasilingam (2020) draws attention to usability in low-touch, transactional settings. This difference suggests that extant research still tends to view trust through narrow, context-specific lenses, offering limited insight into how functional features support trust across different tourism experiences.

Within the hospitality industry, Marghany et al. (2025) confirmed that performance and effort expectancy both shape users' attitudes and intentions to engage with hotel service robots, with trust acting as an important nexus between these factors. Similarly, Zhu et al. (2023) found that interaction and information quality of AI chatbots significantly increase potential tourists' trust and purchase intention, with perceived usefulness mediating these relationships, and product familiarity strengthening the link between perceived usefulness and trust. Their results align with the framework proposed by Belanche et al. (2020) , who argued that functional capability forms the backbone of customer acceptance and satisfaction. When chatbots operate smoothly, provide reliable information, and integrate well with the wider service environment, they reduce uncertainty and increase user confidence. Zarouali et al. (2018) found similar results on social-media platforms, where perceived usefulness and positive prior attitudes predicted people's willingness to interact with chatbots. This finding mirrors how travellers are more likely to rely on AI systems that offer accurate and personalised recommendations.

The credibility and relevance of the information that chatbots provide also strongly influence trust. Shi et al. (2021) showed that accurate, timely, and customised information reduces uncertainty and builds cognitive trust, especially in high-stakes travel planning. Orden-Mejía et al. (2025) added that enjoyable and easy interactions with destination chatbots enhance both perceived usefulness and satisfaction. While both studies highlight the value of information quality, they take different perspectives. Shi et al. (2021) focus on trust as a rational, risk-reducing process, whereas Orden-Mejía et al. (2025) view it as part of an emotional experience that increases engagement. This contrast reflects a broader pattern in chatbot research, where trust is often seen as either instrumental or emotional, rather than a combination of both. Therefore, these studies show that functional trust rests on performance, usability, and credible information, but it also interacts with emotional engagement. A well-designed and reliable chatbot does more than perform tasks efficiently; it builds the foundation for deeper user connection and lasting trust across different stages of the tourism experience.

Emotional and relational aspects of trust: The affective view

Although functional competence forms the foundation of trust, emotional and relational qualities are becoming increasingly important in tourism contexts. As digital interactions become more sophisticated, users begin to judge

chatbots not just by performance but by how they make them feel. Nguyen et al. (2023) found that empathetic and friendly responses enhanced perceptions of social presence, which strengthened trust. Pelau et al. (2021) similarly reported that responsiveness and emotional expressiveness increased perceptions of anthropomorphism and trustworthiness. However, Scarpi (2024) alerted that when empathy feels artificial, interactions with non-human agents may threaten users' sense of identity and belonging. These findings reveal that emotional design can both reinforce and undermine trust. To succeed, chatbots must align empathetic cues with users' psychological needs and social expectations, ensuring emotional comfort rather than alienation.

Empathy and responsiveness transform functional exchanges into genuine relationships. de Kervenoael et al. (2020) suggested that tourists are more willing to engage with social robots when they perceive understanding and care. Chatbots that listen attentively and respond in emotionally intelligent ways are seen as companions rather than tools. Yu (2020) found that guests described friendly and humorous robots as trustworthy, whereas cold or mechanical behaviour reduced satisfaction. Belanche et al. (2020) explained that trust develops through the interaction of technology design, user attitude, and service context. Marghany et al. (2025) further demonstrated that appealing design and perceived social value directly shape positive attitudes and trust in hotel service robots. As a result, this demonstrates that emotional engagement allows AI systems to build relationships that extend beyond transactional efficiency, fostering loyalty and connection in tourism experiences.

The emotional side of trust extends beyond interface design to how organisations use AI responsibly. Bock et al. (2020) argued that as AI becomes embedded in services, it reshapes perceptions of transparency, fairness, and integrity. Users must feel that empathy is genuine and that the organisation behind the chatbot acts ethically. Cultural and aesthetic factors also play a crucial role. Folk et al. (2025) found that East Asian users tend to hold more favourable attitudes toward chatbots than Europeans, partly because they are more receptive to anthropomorphic design. Ciechanowski et al. (2019) observed that overly realistic avatars can cause discomfort through the uncanny-valley effect, whereas stylised designs feel more natural. This highlights the need for emotional realism balanced with cultural awareness. Overall, trust develops when users perceive chatbots as socially aware, emotionally responsive, and ethically sound. AI Chatbot designers and organisations must move beyond scripted politeness to create culturally attuned and psychologically grounded interactions. When empathy feels sincere and design aesthetics evoke comfort, users experience social presence that deepens their confidence in AI systems. In tourism, where emotions shape experiences, this relational form of trust can be as influential as functionality in determining whether travellers continue to engage with AI-powered services.

Trust erosion: When chatbots fail to connect

Although efficiency is often cited as a key advantage of AI chatbots, unmet emotional needs can actively undermine customer trust, particularly in tourism, which is an emotionally sensitive service. Husnain et al. (2025) identified brand irritation, lack of distinctiveness, and feelings of powerlessness as key drivers of brand hate, emphasising that these are not fleeting frustrations but deep psychological responses. Similarly, Scarpi (2024) argued that the absence of psychological ownership in chatbot interactions reduces users' sense of control and belonging, gradually eroding affective trust. These findings show that poor chatbot interactions, such as cold or impersonal responses, can trigger detachment, resentment, and even online retaliation. Therefore, trust breakdowns stem not only from technical shortcomings but also from emotional failures. For chatbots in tourism, integrating emotional intelligence and genuine responsiveness is essential to maintaining user confidence and avoiding long-term reputational harm.

Trust erosion intensifies when users interpret technical or contextual failures as signs of indifference or disre-

spect. Husnain et al. (2025) found that 75% of users became frustrated when they could not escalate issues to a human agent, and 59% expressed irritation when forced to repeat themselves due to poor contextual memory. These experiences are not perceived as minor inconveniences but as evidence of communicative insensitivity that damages brand relationships. Scarpi (2024) added that when chatbots lack contextual awareness, users feel emotionally disconnected and are less likely to rebook or engage in repeat interactions. Interpreted through the Stimulus–Organism–Response (SOR) model, chatbot insensitivity acts as a stimulus that provokes dissatisfaction and alienation, undermining both trust and loyalty. In emotionally charged service sectors such as tourism, failures of communication quickly translate into failures of trust, highlighting the need for emotionally intelligent escalation pathways and consistent contextual understanding.

When chatbots fail to convey empathy or adaptability, users perceive the technology as uncaring or incompetent. Yu (2020) found that guests described unresponsive hotel robots as awkward and cold, which reduced trust and satisfaction. de Kervenoael et al. (2020) also observed that limited empathy and social presence lowered visitors' willingness to use hospitality robots. Similarly, Adam et al. (2021) reported that rigid, context-blind dialogues weakened user compliance and perceived credibility. This highlights that trust erosion arises from the interplay of technical rigidity and emotional detachment. Once users feel misunderstood or dismissed, they tend to avoid future interactions with chatbots, viewing them as symbols of organisational insensitivity rather than service enhancement. Hence, restoring trust depends on designing systems that listen actively, adapt to user context, and respond with emotional awareness.

Preventing trust erosion depends on an organisation's ability to blend technical reliability with empathy and ethical communication. Bock et al. (2020) warned that when AI systems lack transparency or moral accountability, users interpret mistakes as deliberate neglect. Zarouali et al. (2018) further demonstrated that negative experiences reduce future willingness to interact with chatbots, showing that trust loss is cumulative. To counteract this, organisations must monitor chatbot performance closely, provide human backup options, and design emotionally sensitive interfaces that acknowledge frustration and guide users calmly. In tourism, where service encounters are emotionally rich and personal, even small lapses can damage the sense of care that underpins trust. Combining empathetic dialogue, context-aware communication, and consistent accuracy can help rebuild user confidence and prevent trust from deteriorating into disengagement or brand rejection.

CONCLUSION

This systematic literature review examined how AI chatbots influence customer trust in tourism and hospitality. Three key themes emerged. First, functional attributes such as reliability, responsiveness, and information accuracy were consistently identified as foundations of trust, especially in service-critical contexts. Second, affective and relational qualities, including empathy, anthropomorphism, and cultural sensitivity, enhanced perceptions of social presence and long-term trust, though poorly designed cues risked alienation. Third, the findings highlighted the fragility of trust, as unmet emotional expectations and technical shortcomings could escalate into dissatisfaction, reputational harm, or even brand hate. These insights emphasise that customer trust in AI chatbots depends on a careful balance between technical efficiency and emotional intelligence.

The review also points to two underexplored areas for future research. The first is trust repair, particularly the effectiveness of recovery strategies, such as apologies, transparency, and empathic design, after negative chatbot experiences. The second is non-user trust, where passive audiences may form impressions of chatbot credibility without direct interaction. Addressing these gaps will refine theoretical models of trust by incorporating resilience

and indirect perception, while also guiding tourism providers in designing chatbots that support both active users and bystanders.

This review is limited by its reliance on 25 studies, may not reflect the full breadth of emerging research. In addition, certain dimensions, such as privacy, ethics, and multi-channel integration, remain underrepresented. Future research could expand the evidence base and explore longitudinal and cross-sectoral perspectives to capture the evolving dynamics of trust in AI-enabled tourism.

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Literature Review

Blockchain Applications in Healthcare Supply Chain: A Systematic Review on Enhancing Traceability and Security from a Data Analytics Perspective

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ABSTRACT

With the rapid advancement of digital technologies, improving traceability and security has become a primary objective for healthcare supply chains seeking to ensure product authenticity and patient safety. This study used a systematic literature review to investigate the application of blockchain technology, alongside data analytics to improve transparency, traceability, and security in healthcare supply chains using PRISMA guidelines. Peer-reviewed articles published between 2015 and 2025 are used in this investigation, and the findings are structured using the Technology-Organisation-Environment framework. The findings indicate that blockchain can offer immutable transaction records and enable real-time monitoring across the healthcare supply chain. Additionally, data analytics are useful in risk identification, selection of decisions, and effective supply chains. There are still several obstacles such as the high cost of implementation, insufficient staff training, system integration problems, and poor legal frameworks. This study proposes addressing these issues with the help of pilot projects, enhancing skills of the staff, and developing collaboration between organisations.

Keywords: Blockchain; Healthcare supply chain; Traceability; Patient safety; Data analytics; Technology-Organisation-Environment (TOE)

INTRODUCTION

The supply chains of high-risk medicines and vaccines have become increasingly complex and technologically advanced in recent years. The healthcare supply chains are in a difficult situation when it comes to traceability and safety. Inherent problems of the traditional logistics systems include information silos, impossible tracking, and limited visibility (Hölbl et al., 2018). These issues are capable of interfering with patient safety and drug quality control gravely (Fiore et al., 2023; Jadhav & Deshmukh, 2022).

As digital transformation continues, blockchain technology has become an important tool to improve transparency and trust in supply chains. In this context, blockchain can be understood as a distributed digital ledger in which records are chronologically and cryptographically stored to prevent unauthorised modification (Hasselgren et al., 2020). It enables secure and transparent data sharing within healthcare supply chains (Hasselgren et al., 2020). When combined with data analytics, its value becomes even greater. Data analytics can enable blockchain systems to provide valuable insights, support real-time decision-making, and enhance security, moving well beyond simple record keeping. Within the framework of blockchain-based healthcare supply chains, predictive analytics takes place based on the data flows (scans) recorded by Internet of Things (IoT) sensors, including temperature, humidity and location, which are stored on the blockchain directly or addressed via cryptographic hash. IoT devices may operate

alone but combining them with blockchain provides the integrity of data, provenance, and multi-party trust that is crucial in the regulatory requirements of specific laws, including the U.S. Drug Supply Chain Security Act (DSCSA). Even though blockchain is not a solution to real-time computation, it should be connected to off-chain analytics systems to facilitate close-to-real-time feedback and anomaly detection (Munasinghe & Halgamuge, 2023; Sim et al., 2022).

The organisation and safety of the blockchain systems are the concern of many contemporary studies. Few of them discuss the use of data analytics in enhancing blockchain in terms of tracking and safety. Although other studies do recognise the concept of organisational conservatism and stakeholder complexity in healthcare (Agbo et al., 2019; Fiore et al., 2023; McGhin et al., 2019; Oliveira & Martins, 2011), a lot of literature still puts emphasis on technical feasibility. Specific sector barriers, including regulatory reservations, fragmented governance, and institutional asymmetric capabilities, are relatively under-researched (Kumar et al., 2025; van Hoek, 2020). This is why the present literature review aims to address this gap. It analyses the research from three perspectives, namely Technology-Organisation-Environment (TOE). The aim of this investigation is to generate both practical insights and academic contributions that support the development of more traceable and safer healthcare supply chains.

LITERATURE REVIEW

This section summarises existing research on blockchain and data analytics in healthcare supply chains, structured around the TOE framework. The following discussion examines three key dimensions of blockchain adoptions: technological capabilities, organisational readiness, and external environmental forces. The last remaining sections further examine each dimension of TOE, providing major drivers, and barriers to the implementation of blockchain within healthcare supply chains, as well as outcomes.

Technology dimension

The technological aspect underscores the importance of blockchain infrastructure, smart contracts, IoT sensors and analytics platforms toward the delivery of transparent and responsive healthcare logistics. Blockchain-based smart tracking and tracing systems create decentralised, tamper-proof records that monitor drugs from production to the point of care, that is, the stage where medicines reach hospitals, pharmacies, or patients (Fiore et al., 2023). In fact, in real-life scenarios, blockchain has mitigated these old problems in several operational ways. For example, the threat of counterfeits is minimised since every batch of medicine is assigned a unique digital identifier that is referred to in the ledger and authenticity can be confirmed at any point during the hand-off. Inventory imprecision is minimised by real-time updates of the IoT sensors and automatic reconciliation using smart contracts. All these characteristics allow establishing end-to-end visibility and reliable data exchange between manufacturers, distributors, and healthcare providers, minimising the manual paperwork, compliance time, and expenses (Jadhav & Deshmukh, 2022).

Although the majority of the reviewed studies claim blockchain can provide tamper-proof records, these studies are mostly based on theoretical models or small-scale pilots, lacking verification data from large-scale actual deployment. This highlights the need to focus on the actual effects in complex healthcare environments.

The IoT sensors are useful in tracking the product status when it is in transit, including temperature, humidity and position. Such sensors send real-time information to blockchain nodes, which subsequently record irreversible timestamped and condition logs (Singh et al., 2020). New study indicates that the combination of IoT and blockchain can enhance efficiency of information technology activities in pharmaceutical supply chain (Chen et al., 2023), as well as solve the related complicated issues to increase the visibility, flexibility, and disruptions of such activities, especially when it comes to breaking the risk of disruption inherent to the COVID-19 pandemic (Sim et al., 2022). The existing

healthcare professionals have already been overwhelmed since COVID-19. The implementation of new blockchain systems can lead to the complexity of their operation, which is highly understated in the current studies (Jadhav & Deshmukh, 2022; Sim et al., 2022).

Regarding implementation platforms, the current body of knowledge reveals a number of blockchain frameworks, which can be applied in healthcare environments. Using Ethereum-based systems has the benefit of smart contract functionality, so the compliance process is automated, and anomalies are detected (Marino & Diaz Paz, 2025). A permissioned blockchain Hyperledger Fabric is also quite popular because of the sensitivity and privacy of health-related data as this aspect offers improved security and privacy levels that can be applied to healthcare supply chain management (Sim et al., 2022).

Based on these operational capabilities, data analytics is another way to expand the value of blockchain in healthcare supply chains by converting documented information into actionable insights. In this context, responsiveness means the capability to identify and react to risks before product quality or availability is impaired. Analytics platforms enable real-time monitoring and response to potential disruptions. They generate early warnings using blockchain-verified, time-stamped records. To illustrate, cold-chain failure can be detected based on the analysis of temperature variations or shipping anomalies (Munasinghe & Halgamuge, 2023; Sim et al., 2022). Blockchain-based dashboards contribute to enhanced transparency and coordination of manufacturers, distributors and healthcare providers, whereas predictive analytics assists regulating agents to predict recalls and enhance compliance preparedness (Jadhav & Deshmukh, 2022).

Organisation dimension

The organisational dimension highlights the internal challenges that healthcare institutions encounter when attempting to adopt blockchain-based traceability systems. Across the literature, organisational preparedness is consistently identified as a crucial determinant of whether digital transformation efforts succeed. Most studies emphasise three core organisational factors that shape blockchain adoption: the strength of data-governance capabilities, the digital literacy of employees, and the organisation's overall openness to innovation (Fiore et al., 2023; Jadhav & Deshmukh, 2022). However, while these works point to the need for technical training and workflow redesign, they pay considerably less attention to the broader coordination challenges that arise when multiple healthcare organisations must collaborate. In reality, many healthcare providers still rely heavily on fragmented legacy information systems, creating a wide gap between the optimistic technological narratives in academic discussions and the practical constraints faced in everyday operations (Agbo et al., 2019; McGhin et al., 2019). These disparities suggest that future research should move beyond conceptual arguments and examine how institutions can build genuine readiness—through improved governance mechanisms, clearer incentive structures, and more effective cross-organisational cooperation—to support real-world blockchain deployment.

In healthcare supply chains, data governance is key. Different levels of digital maturity among stakeholders often lead to data silos and inconsistent workflows (Fiore et al., 2023; McGhin et al., 2019). Deploying centralised data architectures such as master data management systems is considered helpful in eliminating data redundancy and improving real-time visibility and accuracy of prescription and inventory information (Kumar et al., 2025; van Hoek, 2020).

Employee capabilities and digital resistance are also major organisational barriers. Research by Sim et al. (2022) and Agbo et al. (2019) emphasises that structured, role-specific digital-literacy programmes and performance-support systems, such as embedded help, simplified interfaces, and technical help desks are required. Although

technical structures are becoming more mature, little research has critically addressed the sustainability of blockchain implementation in the high-energy-consumption environment, an issue that is particularly critical to healthcare operations with cost constraints (Fiore et al., 2023; Kasyapa & Vanmathi, 2024). Moreover, the costs of implementing blockchain estimated in some studies might be too optimistic and do not cover the financial feasibility factor of implementation in small and intermediate healthcare entities (Jadhav & Deshmukh, 2022; Munasinghe & Halgamuge, 2023).

Environment dimension

The environment dimension identifies how the external factors are important in determining blockchain adoption in the healthcare supply chain. National strategies of digital health, regulatory frameworks, and competitive market forces are considered the key driving or inhibiting forces to successful implementation. Such external pressures are stimuli and limitations at the same time, and they ensure challenging operational conditions that healthcare organisations have to manage successfully (Agbo et al., 2019; Katuwal et al., 2018). Current research mainly focuses on the adaptability of policy standards and technical interoperability, but discussion of potential tension between patient privacy protection and supply chain transparency is relatively limited. This issue is particularly critical in the healthcare field. Although blockchain systems can enhance transparency and traceability, excessive data visibility may raise ethical risks of patient privacy leakage. Additionally, regarding responsibility mechanisms when blockchain systems fail or data errors occur, current literature lacks systematic discussion. As blockchain is widely deployed in healthcare scenarios, such ”accountability mechanism gaps” may become key bottlenecks in practical applications (Beck et al., 2017; Xu et al., 2019).

The environmental dimension in the TOE framework includes external influences on the adoption of technology, such as regulatory, policy, and market conditions (Oliveira & Martins, 2011). In healthcare supply chains, regulatory uncertainty is one of the most common environmental challenges that have been identified as reasons to implement blockchain. The ongoing development of digital-health policies, such as requirements for drug traceability, electronic prescription, and health-information-exchange regulations, has generated persistent interoperability challenges between national health platforms and commercial healthcare providers (Radanović & Likić, 2018; Zhang et al., 2018). The cross-institutional deployment of blockchain systems is highly complicated by the differences in data sovereignty and healthcare liability across the national judicial systems.

Limitations

There are a few limitations of this systematic review that should be seen. To begin with, it is restricted to English-language peer-reviewed articles that are published within the period of 2015-2025. Although this period represents the recent advancements of the blockchain technology in the healthcare sector, it might not include more recent and applicable research in other languages or grey literature, which might include industry reports and white papers containing more practical information. Second, existing literature has limited the findings based on its quality. As it has been mentioned above, the majority of present-day research is dependent on theoretical perspectives or pilot projects instead of the large-scale real-life application. It makes it hard to come up with solid conclusions regarding the effectiveness of blockchain in a complicated healthcare setting. Third, blockchain technology is evolving at a high pace and, therefore, some of the most current developments and practices in the industry might not appear in peer-reviewed articles yet. It is not unusual to find that there is a period after an event occurs in industry and it is published in academic journals. Lastly, despite the fact that the TOE framework can offer a valuable approach

to the analysis of factors influencing the adoption of blockchain, it might not represent all the unique issues that various healthcare organisations or health systems in various regions may encounter. In spite of these shortcomings, this review nevertheless gives a valuable overview of what is known to date and what areas are omitted that further research should focus on, especially in terms of applying blockchain to healthcare supply chains.

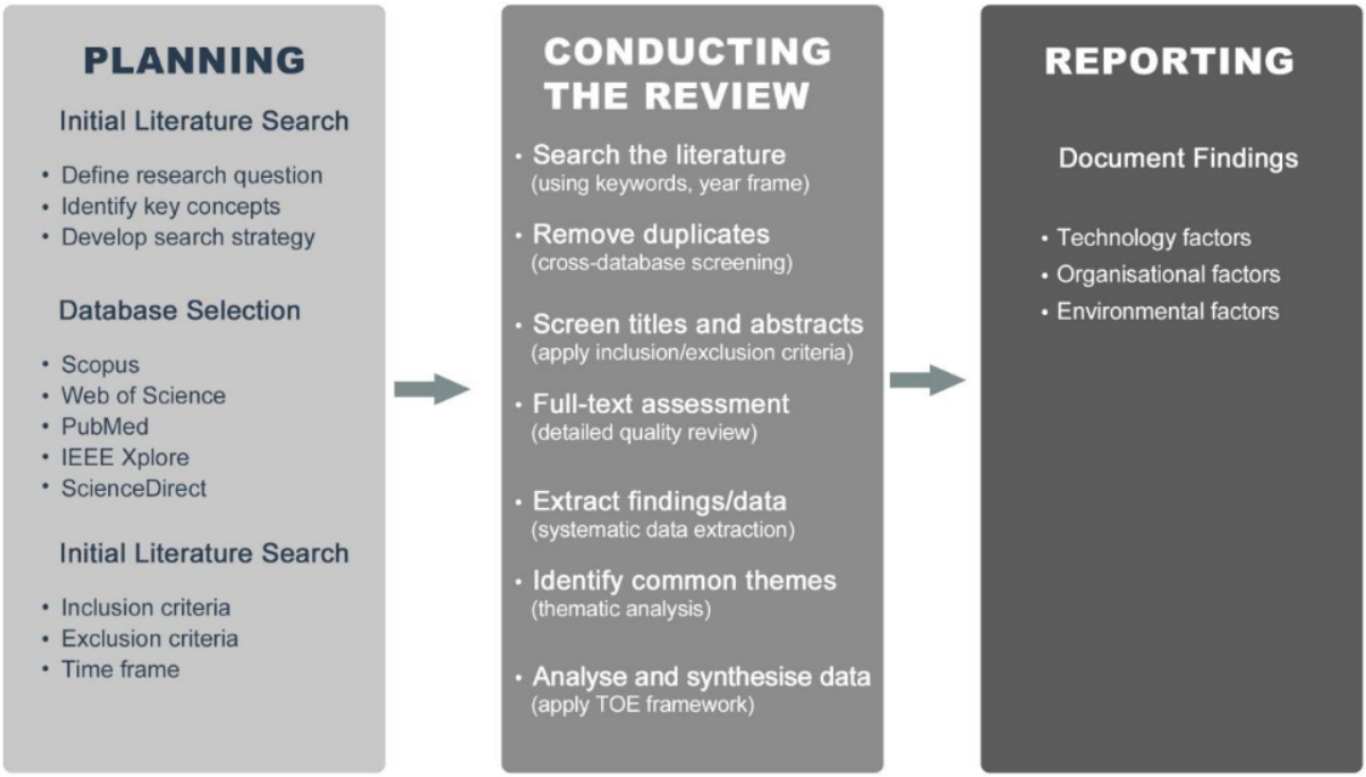
RESEARCH METHODS

This research applies the systematic literature review approach. This is to gather and examine available literature on the application of blockchain and the use of data analytics in enhancing the aspect of traceability in healthcare supply chains and ensuring safety.

The Boolean search string has been used, and the keywords were as follows: blockchain AND healthcare supply chain AND traceability OR safety AND data analytics OR predictive OR dashboard. The criteria for inclusion were peer-reviewed articles published between 2015 and 2025 and written in the English language, as well as articles that showed a clear connection to the domain of data analytics or blockchain in healthcare supply chains. This research also had to take account of the direct relationship to traceability or safety effects. Articles that were commentaries, non-reviewed publications, theoretical studies that lack practical evidence, studies that were not part of the logistics in the healthcare industry were not included.

In total, around 40 articles were found during the initial search. After applying the selection criteria, 25 peer-reviewed articles were included in the final review. The screening process followed the PRISMA guidelines (Moher et al., 2009). Then, the selected articles were analysed using the TOE framework. This helped to identify the key factors related to the adoption of blockchain and data analytics from technical, organisational, and environmental

Figure 1: Systematic Literature Review Procedure Based on TOE Framework.



perspectives. The whole search and selection process is shown in Figure 1.

Theoretical Framework

This study uses the TOE framework as the main theoretical perspective. The TOE framework was introduced by Tornatzky and Fleischer (1990). It includes three important aspects that influence the adoption of new technologies: technology, organisation, and environment. This framework helps researchers understand how both internal and external factors affect digital transformation in complex industries like healthcare.

Compared to models such as the Technology Acceptance Model (TAM) or the Diffusion of Innovations (DoI), which focus primarily on individual-level behavior, the TOE framework provides a broader view at the system level. It is especially useful in healthcare, where strict regulations and complicated organisational structures are common (Oliveira & Martins, 2011). TOE brings together many factors from different levels and helps to explain how technologies like blockchain are adopted in healthcare supply chains.

In this study, the TOE framework is also used to show a special challenge in the healthcare field; the issue of responsibility. If a system fails, it could directly affect patient safety. Because of this high-risk nature, many healthcare institutions are very careful about adopting new technologies. This is an important reason why the TOE model fits well in this research.

DISCUSSION

This article provides valuable theoretical and practical contributions by synthesising evidence on the technological, organisational, and environmental factors influencing blockchain adoption in healthcare supply chains. The review highlights that blockchain, supported by data analytics, can enhance system transparency and safety.

Key themes

A synthesis of the 25 peer-reviewed articles reveals three dominant thematic patterns centred around technological capabilities, organisational preparedness, and environmental constraints, aligning closely with the TOE framework. From a technological standpoint, most studies emphasise blockchains immutability, decentralised verification mechanisms, and its integration with IoT devices to enhance traceability and prevent counterfeiting within pharmaceutical supply chains (Casino et al., 2019; Fiore et al., 2023; Singh et al., 2020). A related theme is the increasing incorporation of data analytics to support anomaly detection, predictive risk assessment, and improved visibility in cold-chain environments (Munasinghe & Halgamuge, 2023; Sim et al., 2022). On an organisational level, research points at the ongoing issues of digital maturity, legacy systems, employee skills, and governance coordination by multi-stakeholder networks Agbo et al., 2019; McGhin et al., 2019. The necessity of structured training, data governance frameworks and cross-institutional collaboration are the subject of many papers, and the three elements are often mentioned as these requirements must be met before adoption of blockchain can become successful. Lastly, regulatory fragmentation, data-privacy requirements, and the development of national policies that relate to digital-health are brought up as key themes (Hasselgren et al., 2020; Radanović & Likić, 2018). Throughout the literature, it is agreed that blockchain will be unable to realise its potential benefits without manoeuvre through these complicated external constraints, especially in high-risk healthcare environments.

Areas of concurrence and discord in the literature

Throughout the literature reviewed, it is apparent that blockchain has a high degree of consensus in improving

transparency, data integrity, and traceability in healthcare supply chains. Numerous authors emphasise blockchain's tamper-proof ledger as an effective mechanism for mitigating counterfeit pharmaceuticals (Fiore et al., 2023; Vazirani et al., 2020). Likewise, there is broad consensus that integrating IoT with blockchain enhances monitoring accuracy and enables real-time quality assurance throughout cold-chain logistics (Chen et al., 2023; Singh et al., 2020). However, the literature diverges on several important issues. First, researchers disagree about the scalability and operational feasibility of blockchain in real-world healthcare environments. According to some research, it has been argued that permissioned blockchains like Hyperledger Fabric provide viable performance benefits (Sim et al., 2022), and others have noticed that energy consumption, latency, and transaction throughput are problematic (Kasyapa & Vanmathi, 2024). Second, there are varying costs interpretations of blockchain by the authors: some claim that it is cost-efficient in the long-term by decreasing fraud and paperwork (Jadhav & Deshmukh, 2022), whereas others state that it is prohibitive upfront due to its implementation by small and medium healthcare providers (van Hoek, 2020). Lastly, regulatory frameworks have been called into question on whether they are mature or not - some claim to have advanced towards establishing standards (Hasselgren et al., 2020), others point to the lack of legal settlements between data immutability and privacy rights, including the right to erasure in General Data Protection Regulation (GDPR) (Sabiri et al., 2025). These discrepancies highlight the necessity of sector-based application strategies that are contextualised.

Technological dimension: security enhancement and anti-counterfeiting mechanisms

From the technological dimension of the TOE framework, blockchain provides essential mechanisms to enhance security and prevent counterfeiting. The results of multiple studies (Casino et al., 2019; Fiore et al., 2023; Vazirani et al., 2020) are consistent: blockchain enhances the traceability of drugs by providing immutable and minimise the risk of counterfeit, as well as enhancing accountability. Each drug is assigned a digital signature that is captured onto the blockchain during production and therefore can be authenticated at every point. That forms what scientists refer to as a digital fingerprint of all pharmaceutical products flowing through the pharmaceutical supply chain (Casino et al., 2019).

Data analytics also augments the counterfeit detection potential by tracing the supply chain patterns on the identification of suspect activity or unusual transactions. The algorithms of machine learning would allow identifying atypical routes of shipping, abnormal storage conditions, or unusual transaction patterns that can reflect the arrival of fake products into the supply chain (Hasselgren et al., 2020; Hölbl et al., 2018). To give an example, any deviation from temperature parameters in batches of vaccines can automatically raise alerts and get investigation processes started (Hastig & Sodhi, 2020). These studies collectively highlight blockchain's ability to ensure the integrity of data by distributed ledger architecture, and avoid unilateral manipulation of data (Zhang et al., 2018). However, according to Mettler (2016), the technology cannot eliminate the issue of garbage-in, garbage-out, as it is important to ensure data input and validation rules are in place.

Collectively, these articles provide an opportunity to draw the conclusion that the security and the transparency of traceability is based on the technological characteristics of blockchain, especially, immutability, decentralisation, and data-verification processes.

Organisational dimension: real-world implementation cases and lessons learned

Pilot projects might also provide valuable insights into the way blockchain can be implemented in real healthcare networks, on the organisational level. One example is a popular project, the MediLedger, a blockchain consortium

designed by the pharmaceutical industry that shows how decentralised systems can be used in practice to facilitate reliable drug-verification processes (Fiore et al., 2023). Nevertheless, it should be understood that such a case possibly includes survivor bias (Jadhav & Deshmukh, 2022). Participating companies are mostly resource-rich industry giants with outstanding technical capabilities. Therefore, the adopted architecture and processes may not be universally applicable. Especially for small and medium-sized enterprises that constitute the majority of global healthcare supply chains, it may be difficult to replicate this model's technical deployment and governance mechanisms (van Hoek, 2020).

Another notable case is the collaboration between Walmart and IBM in food safety, which has lessons for pharmaceutical applications (Agbo et al., 2019). This responsive rate would be a revolution to the recalls of drugs, which may save lives that might be lost in the process of isolating and recalling harmful products in the market. All these organisational experiences demonstrate that the success of the implementation of blockchains will require resource capacity, collaborative governance, and long-term investment in digital infrastructure.

Environmental dimension: regulatory and compliance considerations

From the environmental dimension, the existing regulatory conditions are likely to offer advantages as well as difficulties in executing blockchain in the healthcare supply chain. On the one hand, the drug Supply Chain Security Act (DSCSA) by FDA mandates the pharmaceutical industry to install electronic track and trace by 2023, which gives a definite regulatory push towards blockchain (Fiore et al., 2023; Sim et al., 2022). Conversely, the rapidly changing and sometimes more complex details of the healthcare rules make the implementers of blockchain uncertain of them. The various countries identify different data privacy needs, drug traceability needs, and cross border data sharing needs (Hasselgren et al., 2020; Katuwal et al., 2018).

There is an extra twist with privacy regulations like Health Insurance Portability and Accountability Act (HIPAA) in the United States and General Data Protection Regulation (GDPR) in Europe. Although there are a number of benefits such as blockchain in improving security, it constitutes permanent records, which contrast with the patient's right to delete or change data. While these regulations aim to protect patient data, they also expose governance gaps that must be addressed through adaptive legal frameworks and standardised compliance models. In general, the regulatory fragmentation and the limitation of privacy are one of the significant obstacles to blockchain adoption across borders.

Evidence gaps

Despite the growing body of literature, several important gaps remain across the selected 25 studies. First, most empirical work is based on conceptual models, simulations, or isolated pilot projects, with very limited evidence from large-scale, fully operational healthcare supply chains (Jadhav & Deshmukh, 2022; McGhin et al., 2019). This gap directly affects our understanding of blockchain's performance under real regulatory, organisational, and market pressures. Second, although many studies emphasise the technical strengths of blockchain, far fewer investigate how data analytics can be systematically embedded into blockchain-enabled systems to support proactive risk management, anomaly detection, and decision-making a core focus of this review. Only a minority explicitly link blockchain ledger data with predictive analytics or machine-learning models (Munasinghe & Halgamuge, 2023; Sim et al., 2022). Third, organisational challenges such as multi-party governance, incentive misalignment, and digital-literacy disparities are acknowledged but rarely analysed through empirical investigation, leaving a significant gap in understanding adoption feasibility across diverse stakeholder groups. Finally, the environmental dimension remains underdeveloped, such as

regulatory contradictions, cross-border data policies, and accountability mechanisms are often mentioned but not deeply examined. These gaps justify this review's objective: to synthesise evidence through the TOE framework and emphasise how blockchain, supported by data analytics, can enhance traceability and safety while addressing the under-researched organisational and environmental constraints in real-world healthcare contexts.

Future development directions and considerations

The further development of blockchain-based healthcare supply chains will rely on the balanced improvement of all three TOE dimensions. First, addressing talent gaps by developing cross-disciplinary expertise in clinical practice, data science, and IT systems is crucial for effective implementation (Fiore et al., 2023; Hasselgren et al., 2020; Hölbl et al., 2018). Second, by standardising blockchain across the borders, it is possible to create global traceability networks that would improve drug authenticity and coordination in case of current pandemics or emergencies (Fiore et al., 2023; Munasinghe & Halgamuge, 2023). Finally, the combination of blockchain and smart contracts in insurance and payment systems presents the opportunity of automating reimbursement procedures and decreasing the number of administrative loads, as well as to provide timely access to life-saving drugs (Jadhav & Deshmukh, 2022; Sim et al., 2022). All these improvements are aimed at the creation of a more robust, transparent, and data-driven healthcare supply chain ecosystem.

CONCLUSIONS

In this review, it has been highlighted that blockchain and data analytics integration holds promise to transform healthcare supply chains through enhancing real-time traceability, drug safety, and regulatory compliance. Although multiple barriers still exist at technical, organisational, and regulatory levels, the long-term strategic value indicates that related investment and implementation efforts are worthwhile in the foreseeable future. Research findings highlight the important role of phased deployment strategies, cross-sector collaboration mechanisms, and interdisciplinary capacity building in addressing technology adoption challenges.

However, considering the high sensitivity and system complexity of the healthcare industry, large-scale adoption of blockchain technology may require a longer cycle than existing literature expects. Regulatory approval processes, standard system construction, and coordination mechanisms among multiple stakeholders will constitute more challenging advancement conditions than the technology itself. Future research can further explore integration paths between blockchain technology and global universal standards, payment systems, and patient feedback mechanisms, thereby promoting interoperability and patient-centered transformation of healthcare logistics systems. Ultimately, building a digital, transparent, and highly interconnected healthcare supply chain ecosystem will become a key goal for achieving dual improvement in operational efficiency and clinical value.

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Research Article

Is the Service Sector Ready for Generative AI? A Descriptive Qualitative Assessment

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ABSTRACT

This research examines barriers and solution approaches relating to the deployment of Generative Artificial Intelligence (GAI) in contact centre businesses in the Australasian region. We find six main barriers to implementation and six key methods of strategies to solve the challenges with regard to obstacle responses from management and non-management staff, with a qualitative descriptive analysis of 53 obstacle and 30 solution responses. The most common were Data Quality and Availability (83.0 percent), Integration and Infrastructure (77.4 percent), and Cost and Resource Constraints (71.7 percent). The data shows that there is a strong relationship between the barriers to implementation, as, in fact, data challenges were co-occurring with infrastructure problems (34 instances) and trust concerns (33 instances) often. The solution strategies are not only fragmented but the maximum prevalence is just 16.7%, indicating there is a lack of agreement on the best implementation pathways between stakeholders. The findings suggest a paradox: stakeholders are highly aware of the governance priorities, but they are unable to describe concrete governance mechanisms and innovation frameworks. Our discussion provides evidence-based suggestions for organisations that have struggled with GAI adoption in customer-service situations, focusing on the prioritization of data foundations, integrated capability development, partnership-based strategies, and operationalised governance models for organisations that have struggled with GAI adoption in customer-service situations.

Keywords: Generative AI, Service Sector, Contact Centres, Adoption Barriers, Readiness, and Governance

INTRODUCTION

GAI is a revolutionary technological paradigm with the potential to have a large impact on customer service activities. As mentioned by McKinsey and Company (2023), GAI has the potential to add up to 2.6 to 4.4 trillion USD to the global economy and can automate tasks that now take up 60 to 70 percent of the efforts by employees. GAI will, in particular, transform the way services are provided in contact centre settings, where customer engagement becomes the central business activity, with the benefit of personalisation, faster response times, and increased operational efficiency (Bamberger et al., 2023; Brynjolfsson et al., 2023).

Despite this potential for transformation, the adoption of GAI is low in the contact centre industry. According to survey data, of 1000 US organisations, 62 percent of organisations have yet to adopt GAI tools in work-related tasks (DISCO, 2023), and 50 percent of GAI integration will occur between 2030 and 2060, with the median being 2045 (Chui et al., 2023). This adoption lag is evident even in light of evidence showing that significant productivity gains could be achieved as a result of such adoption. Research by Brynjolfsson et al. (2023) found that the use of GAI-based conversational assistants by customer support agents led to a 14 percent productivity gain, with an even

larger impact for novice and low-skilled employees.

There appears to be a mismatch between realised potential and actual adoption implies that there are major barriers to implementation beyond technical feasibility. Research into these barriers and viable solution strategies is an important need for organisations that wish to use GAI as a competitive advantage. These implementation dynamics can best be studied in the context of contact centres, which are expected to have the highest GAI adoption rates in the customer service industry (Chui et al., 2023) and where customer experience is the main priority of AI-driven change efforts (Gartner, 2023).

This research addresses a notable gap in current knowledge regarding the barriers faced by organisations in adopting GAI technologies and the solution strategies they consider effective. Al-though much of the existing literature describes GAI capabilities and theoretical frameworks, there is limited empirical evidence on practitioner-identified barriers and solutions. Through a systematic review of open-ended stakeholder responses from contact centre organisations in the Australasian region, we offer grounded insights that can be used to drive evidence-based implementation strategies.

The two key questions our research investigates are:

1. What are the major challenges preventing GAI application in the contact centre environment? and
2. What solution strategies do stakeholders consider effective in addressing these challenges?

Through qualitative analysis, including thematic coding, word frequency analysis, and co-occurrence analysis, we map the landscape of challenges and solutions, revealing patterns that provide actionable insights for practitioners.

THEORETICAL BACKGROUND AND CONTEXT

Contact centres are key to customer engagement, influencing brand reputation and satisfaction through personalized interactions (Talbot, 2021). They face challenges like fluctuating productivity, high turnover (with annual attrition costs of 10, 000 to 20,000 USD per agent), and costly training (Buesing et al., 2020). With customer experience as the top priority, noted by 38% of respondents.

Empirical studies show GAI's potential. Brynjolfsson et al. (2023) introduced a GAI assistant to 5,179 agents, boosting productivity by 14%, especially among new and low-skilled workers. This resulted in a 25% reduction in turnover and case escalation, indicating GAI's ability to address human capital challenges and improve service quality across many industries.

However, GAI implementation in contact centres faces challenges. The need for human interaction and relationship-building creates a tension between automation and service quality, as conversations require both AI-supported pattern-matching and human empathy, judgment, and adaptability. Successfully addressing this requires understanding both technical barriers and organizational readiness.

Implementation obstacles in technology adoption literature

Technology adoption literature highlights key barriers to GAI implementation. The TOE framework (Tornatzky & Fleischer, 1990) identifies technological readiness, organizational capabilities, and environmental factors as key determinants. The Technology Acceptance Model (TAM) stresses perceived usefulness and ease of use (Davis, 1989; Venkatesh et al., 2003), while diffusion of innovations theory focuses on relative advantage, compatibility, and complexity (Rogers, 2003).

Recent AI research points to barriers like resource constraints of time, people and money, data issues, integration challenges, and ethical concerns (Rjab et al., 2023). However, most studies examine AI broadly, rather than focusing specifically on GAI in customer service, leaving gaps this study aims to address.

Governance and ethical considerations

GAI implementation presents governance challenges requiring proactive management. Wach et al. (2023) highlight concerns like regulatory compliance, data privacy, intellectual property protection, algorithmic bias, and misuse. The rapid adoption of tools like ChatGPT, which reached 100 million users (globally) in two months in 2023 (Hu, 2023), often outpacing governance development.

Effective governance requires addressing multiple dimensions: unbiased training data, reducing algorithmic bias, maintaining human oversight, protecting intellectual property, and ensuring clear accountability (Janssen et al., 2020; Mondal et al., 2023). They also suggest that organizations must balance innovation with risk mitigation, requiring frameworks that turn principles into actionable policies.

METHODOLOGY

Research design and data collection

The research design adopted in this study was a qualitative-methods research design that using open ended questionnaire as a qualitative data collection tool to examine the GAI application in contact centre businesses in the Australasia region. The qualitative approach used allowed obtaining open-ended qualitative replies, thus providing a story on the issue of implementation challenges (Dawadi et al., 2021; Schoonenboom & Johnson, 2017).

Purposive sampling was used to recruit participants via personalized email messages and LinkedIn messages to both the managerial and non-managerial employees of the contact centre organizations in regulated industries like legal, healthcare, education and finance. in . This sampling plan helped to reach out to the stakeholders who had a first-hand experience and an informed opinion on the problem of GAI implementation (Palinkas et al., 2013). The survey was done online between July and August of 2023 resulting in an 88% response rate.

The composition of the respondents included 62 percent managerial level respondents and 38 percent non-managerial employees, with the largest percentages being insurance, information technology, and healthcare. This composition offered both strategic decision-making (managerial) and operational implementation (non-managerial) levels of view.

Survey instrument

The questions developed in the survey Included? two main open-ended questions that were studied within the frame of this qualitative analysis:

> **Q6:** "What are the challenges that your business encounters in adopting generative AI?" (Multiple selection based on pre-defined options, open-ended expansion).
>
> **Q8:** "What are, in your opinion, the specific actions, strategies, or measures that will help your organization to overcome the possible barriers and challenges to deploying generative AI?" (Open-ended question).

Question 6 had 53 responses with 273 total selections under obstacles categories, and Question 8 had 30 re-

sponses. The survey also included the quantitative data on the readiness to organizational governance and considerations, and this allowed triangulation to be used to confirm the qualitative results.

Analytical framework

The inductive thematic analysis was used in qualitative analysis based on the valid methodologies of using thematic analysis in accordance with the existing guidelines on thematic analysis use (Braun & Clarke, 2006, 2022). All responses were subjected to exhaustive preprocessing, such as to lower ase, punctuation marks, tokenization and extensive stop word removal based on an extended list of non semantic words over 400. This preprocessing resulted in fine corpora of 1,361 extracted meaningful words of obstacle responses and 257 words of solution responses.
Three complementary techniques were incorporated in the analytical framework:

Thematic Coding: The responses were coded into six pre-defined obstacles themes (Technical Expertise & Skills, Data Quality & Availability, Cost & Resource Constraints, Integration & Infrastructure, Trust & Reliability, Ethical Concerns and Legal Concerns) and six themes of solutions (Training & Education, Pilot Projects & Testing, Governance & Policy, Collaboration & Partner-ships, Investment & Resources, Change Management). These themes were informed by theoretical perspectives in adoption of technology, organizational change and implementation of AI literature. The coding involved the application of the keyword matching algorithms which have been tested with the manual classification.

Word Frequency Analysis: The most repeated words in the responses after removing stop words and minimum length filtering (≥ 4 characters) were used in the quantitative assessment to determine the most common words mentioned. They were supported by frequency distributions that assisted the thematic coding findings and identified relevant ideas in the discourse of stakeholders.

Co-occurrence Analysis: Co-occurrence matrix recorded where more than one theme of obstacles was observed in individual responses clarifying interrelations between barriers. Co-occurrence frequencies were normalized to correct different rates of prevalence of the same theme and relationship strengths could be compared.

FINDINGS: IMPLEMENTATION OBSTACLES

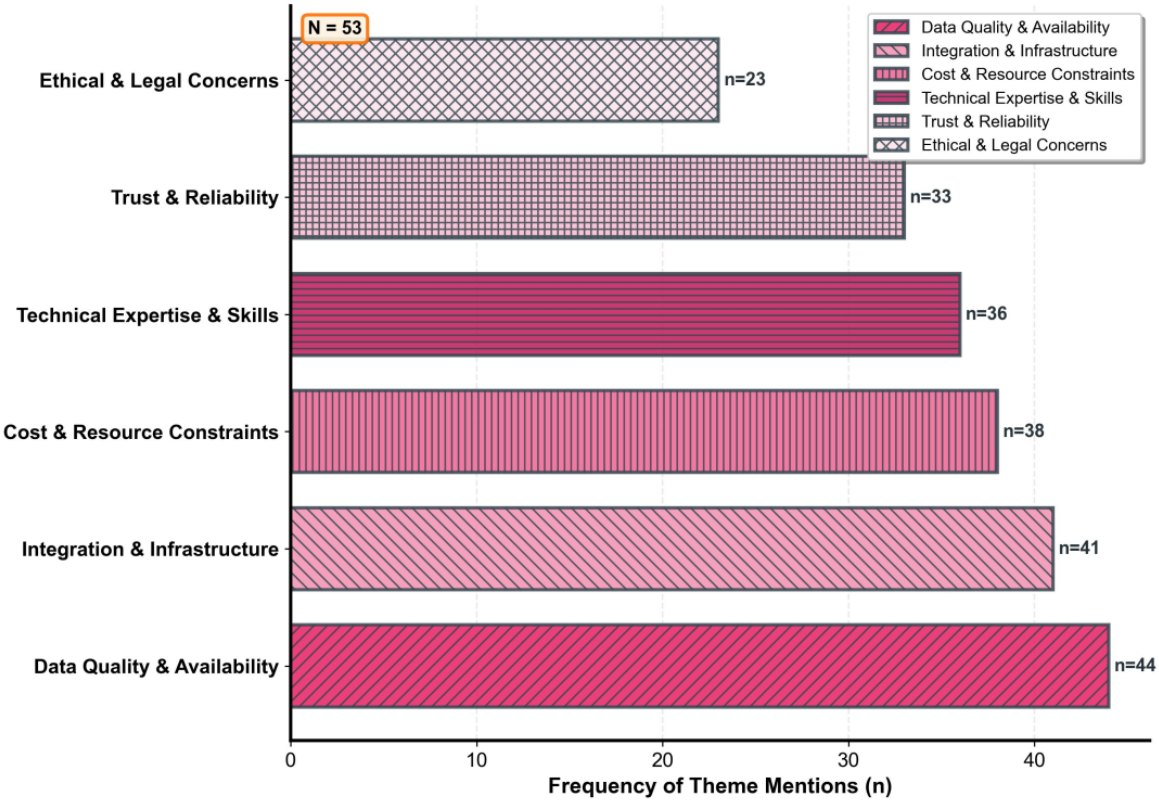
Thematic distribution of obstacles

The thematic content analysis of 53 obstacle responses indicated that six major thematic groups are present that depict clear hierarchical trends that reflect the existence of focused stakeholder issues. The full distribution of obstacle themes is given in Figure 1.

The most common concern was Data Quality & Availability, which was identified by 83.0 percent of the respondents (n=44). The datum highlights a general understanding that General Artificial Intelligence (GAI) systems are essentially data-dependent, and the quality of output is necessarily limited by the nature of input data. The challenges that were highlighted by respondents included completeness, accuracy, relevance and accessibility of data by the organization. The concerns that were represented were fragmentation of data in legacy systems, lack of consistency in quality standards, lack of historical data to use in training and organizational silos that limit access to data. In the second place, with 77.4 percent (n=41), Integration & Infrastructure indicated intense apprehension about technical compatibility and system architecture as well as the issues of integrating AI capabilities into the existing technological ecosystems. This theme includes the limitations of legacy systems, platform compatibility problems, API integration

difficulties, and architectural difficulties connected to developing smooth AI-driven workflows.

Figure 1: Distribution of Implementation Obstacle Themes (N=53)



The Cost & Resource Constraints were reported by 71.7 percent of the respondents (n=38), which included a high start-up capital and continual operation costs. The theme is a financial investment of technology purchase, infrastructure building, acquisition of talents with specialization, an extensive training program and maintenance of systems.

Technical Expertise & Skills 67.9 percent of respondents (n=36) are emphasizing dimensions of critical human capital. The theme includes gaps in knowledge in data science, machine learning engineering, AI system management, and new competencies in prompt engineering and AI ethics.

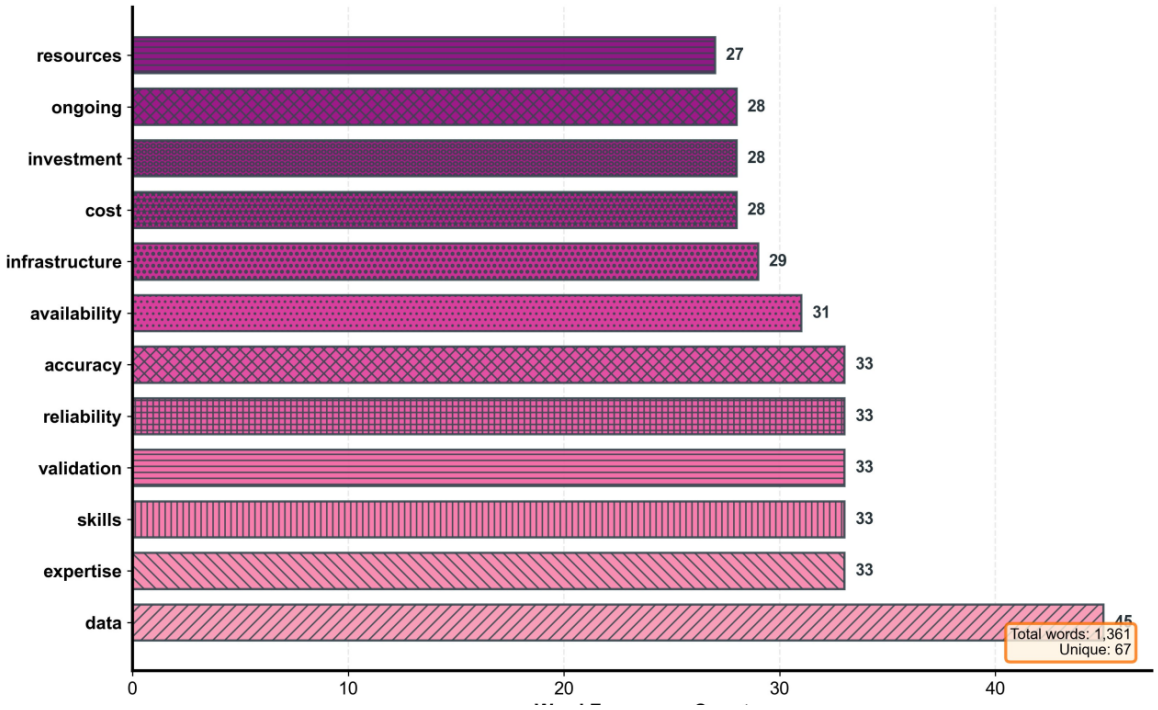
The issue of Trust and Reliability presented in 62.3% of the answers (n=33) shows the fears of the reliability of the AI system, the correctness of the output, and the trust in the use of algorithms in decision making. A need to be explainable, a validation system, a fallback system under AI failure, and the definition of the liabilities of AI-made mistakes were highlighted by the respondents.

Ethical & Legal Concerns ranked lowest (43.4% (n=23)) but still indicated a large minority. The theme consists of regulatory compliance uncertainty, privacy protection requirements, intellectual property issues, risk of algorithmic bias, and general implications to the society.

Word frequency analysis: obstacle discourse

Through lexical analysis, excellent pre-processing produced 67 unique meaningful terms out of the 1,361 word corpus, which brought out salient concepts in stakeholder thinking. Figure 2 represents the frequency distribution of the most common more meaningful words.

Figure 2: Word Frequency Distribution for Implementation Obstacles



Data was the most used word (45 times) which is a very powerful argument to consider the focus of the data on the implementation issues and supports the fact that Data Quality & Availability is the most important topic in the thematic coding. Close clustering was also observed in human capital terms: the frequency of the terms expertise (33 instances) and skills (33 instances) was the same, indicating that the stakeholders also perceive technical competencies and practical expertise as one and the same condition.

Quality and reliability terms also tended to fall together: the word validation (33), reliability (33) and the word accuracy (33) also had the same frequency, which means that the issue of system dependability is regularly looked into by the stakeholders on a variety of levels. A few words connected with infrastructure, such as platforms (29), infrastructure (29), and financial terms, such as cost (28), investment (28), ongoing (28), etc., had a lower but still significant frequency.

Figure 3 illustrates an alternative visualization of the predominance of key terms in a word cloud form.

Figure 3: Word Cloud Visualization of Implementation Obstacles

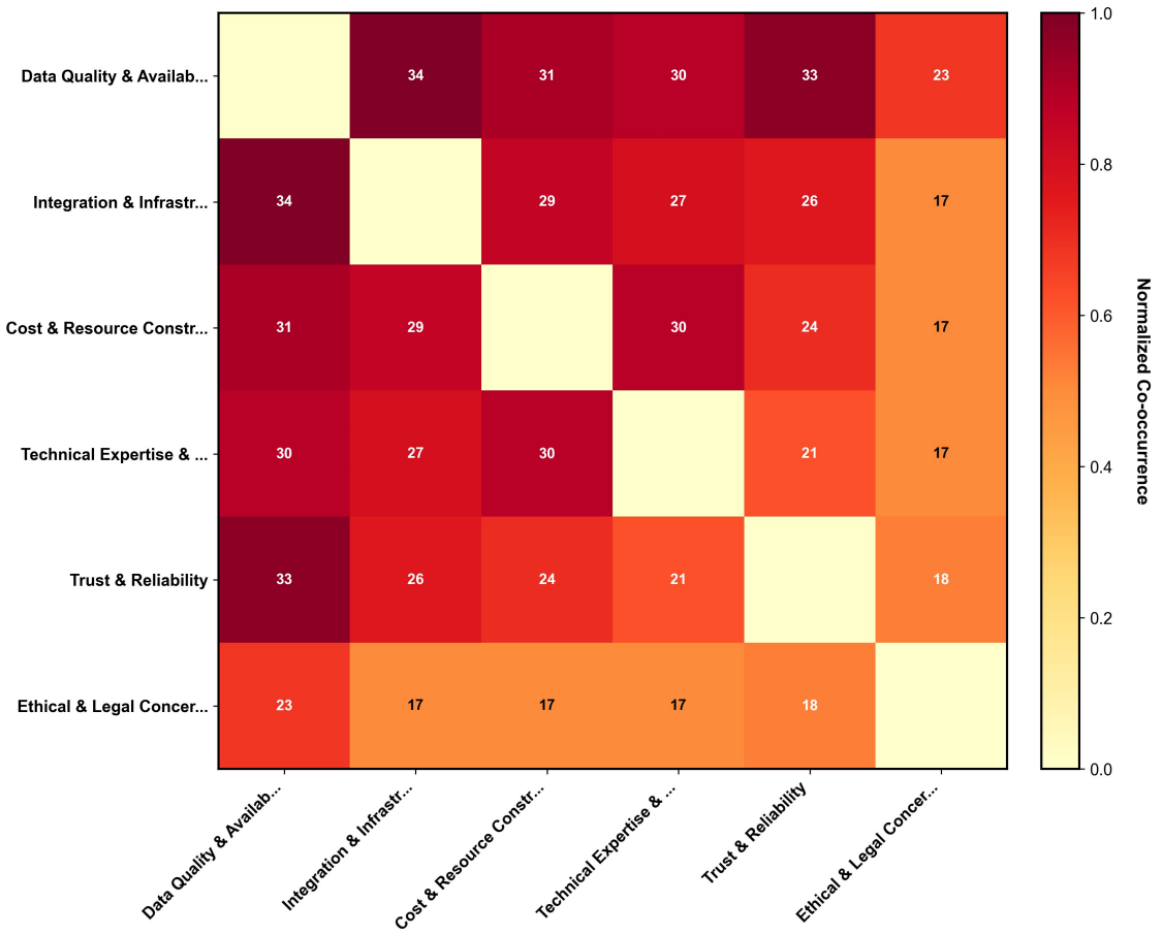
Co-occurrence patterns: interconnected obstacles

The co-occurrence analysis indicates that the implementation barriers are seldom present alone. The co-occurrence matrix (Figure 4) records the occurrences of multiple themes in individual responses, that is, which barriers are clustered in the consciousness of stakeholders.

The highest number of co-occurrences (34 cases) was between Data Quality and Availability and Integration and Infrastructure, indicating that data related issues are inherently tied to the problem of system integration. The close relationship between the concept of Data Quality and Availability and the concept of Trust and Reliability (33 instances) proves that trust issues are usually based on the uncertainties in data quality.

The concept of Data Quality & Availability was often placed with the concept of Cost & Resource Constraints (31 times) and the concept of Technical Expertise & Skills (30 times), which is to show that data issues demand considerable resource involvement and expertise in areas beyond technology purchases alone. These co-occurrence patterns reveal that the implementation barriers are a networked system, and not isolated barriers.

Figure 4: Normalized Co-occurrence Matrix of Obstacle Themes



FINDINGS: SOLUTION STRATEGIES

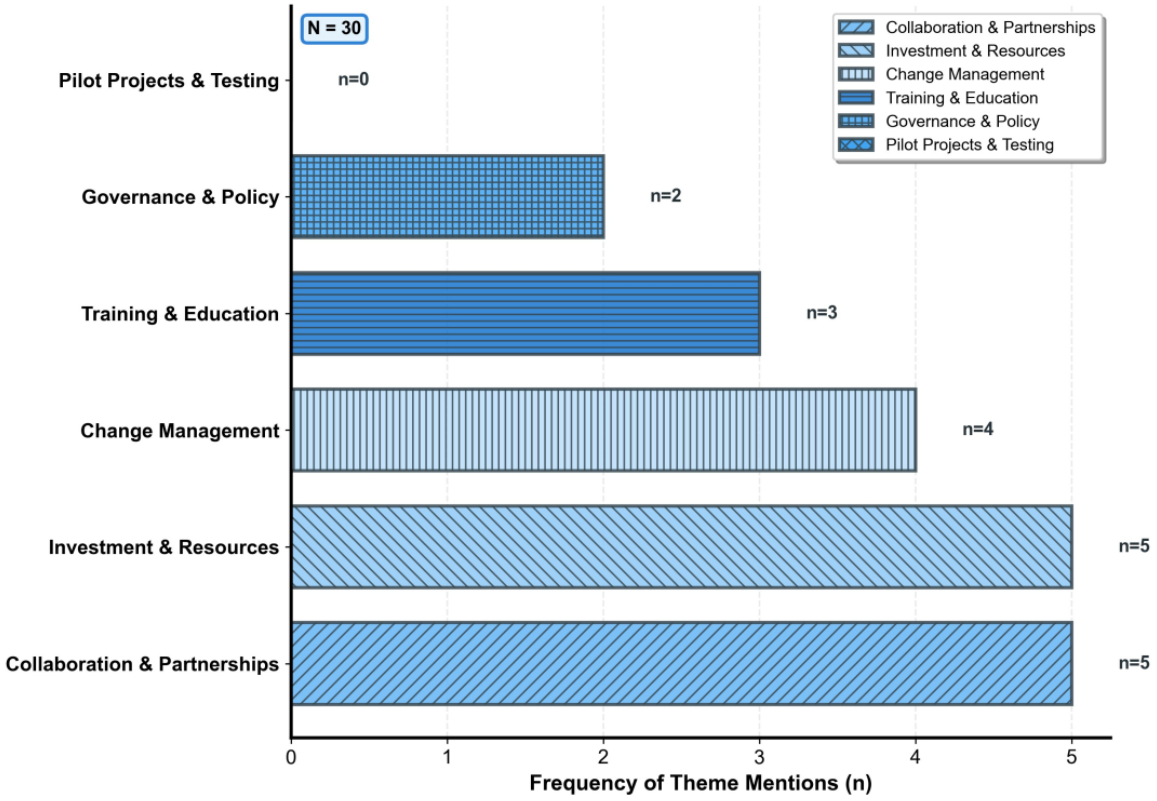
Thematic Distribution of Solutions

The 30 solution responses were also analyzed to find out the six strategic approaches and the results of the analysis have indicated variation among significantly different patterns than the obstacle responses (Figure 5). The decreased response rate (N=30 and N=53) and decreased number of words (257 and 1,361 words) in itself is an outcome of the study—it was more difficult to explain the solutions than to notice the problems.

Both Collaboration & Partnerships and Investment & Resources had 16.7 percent of responses each (n=5), and are the joint-primary solution methods. Collaboration includes using outside AI vendors, teaming with consultants in technology, and industry consortia. The investment is an indicator of appreciation of the fact that successful adoption entails huge resource commitments.

Change Management was mentioned in 13.3% of responses (n=4), with transformation dimensions being human-centered, whereas Training & Education was also mentioned in 10.0 percent of responses (n=3). Governance & Policy appeared in 6.7% of responses (n=2), while Pilot Projects & Testing received no explicit mentions (0.0%) — a striking absence given pilot-driven implementation is a widely promoted best practice.

Figure 5: Distribution of Solution Strategy Themes (N=30)



Word frequency analysis: solution discourse

Patterns of lexical analysis of responses in solutions were quite distinct compared to obstacles (Figure 6). The word human was used most often (5 times) as it focused on the stakeholder acknowledgment that the AI solutions should not eliminate human factors. The word cost (5 instances) was equally common, which shows that the consideration of finances is most important even during the proposal of solutions.

The vocabulary richness is remarkable - the number of unique words, 190 out of 257 in total, shows that the conceptualizations of solutions are very diverse, and there is no real consensus on the particular method. This is in contrast to obstacle responses whereby terminology was more clustered which indicates a better understanding of challenges rather than solutions. Figure 7 is a word cloud visualization of solution discourse.

Figure 6: Word Frequency Distribution for Solution Strategies

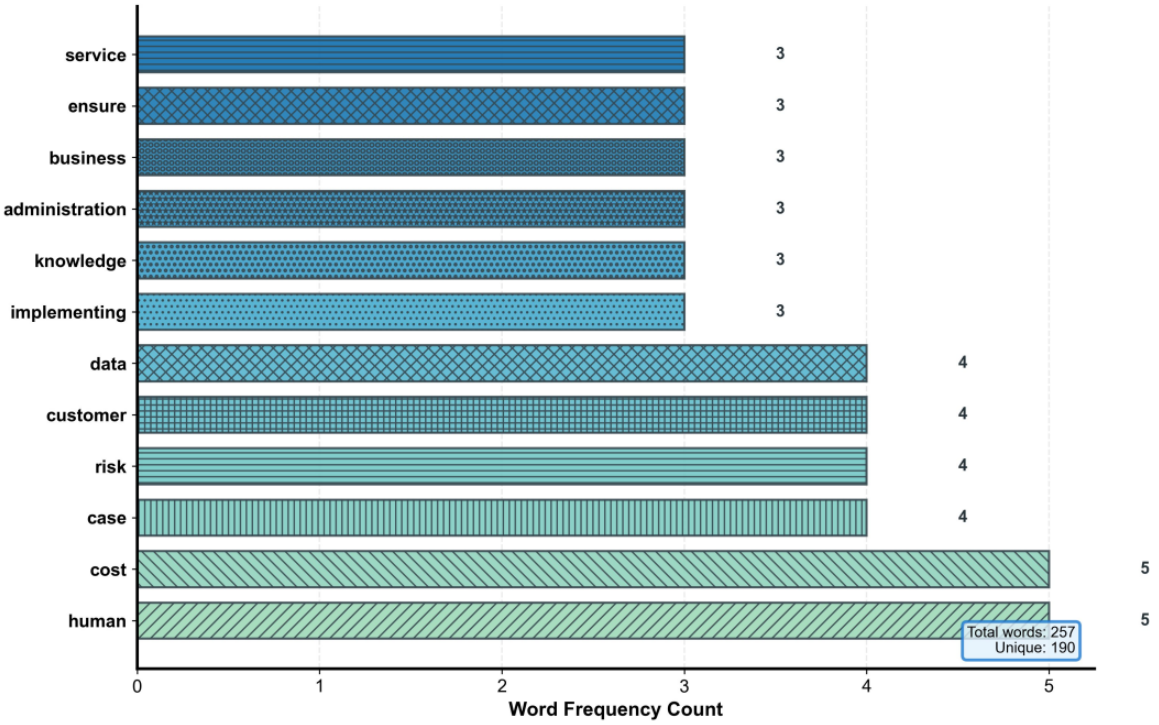


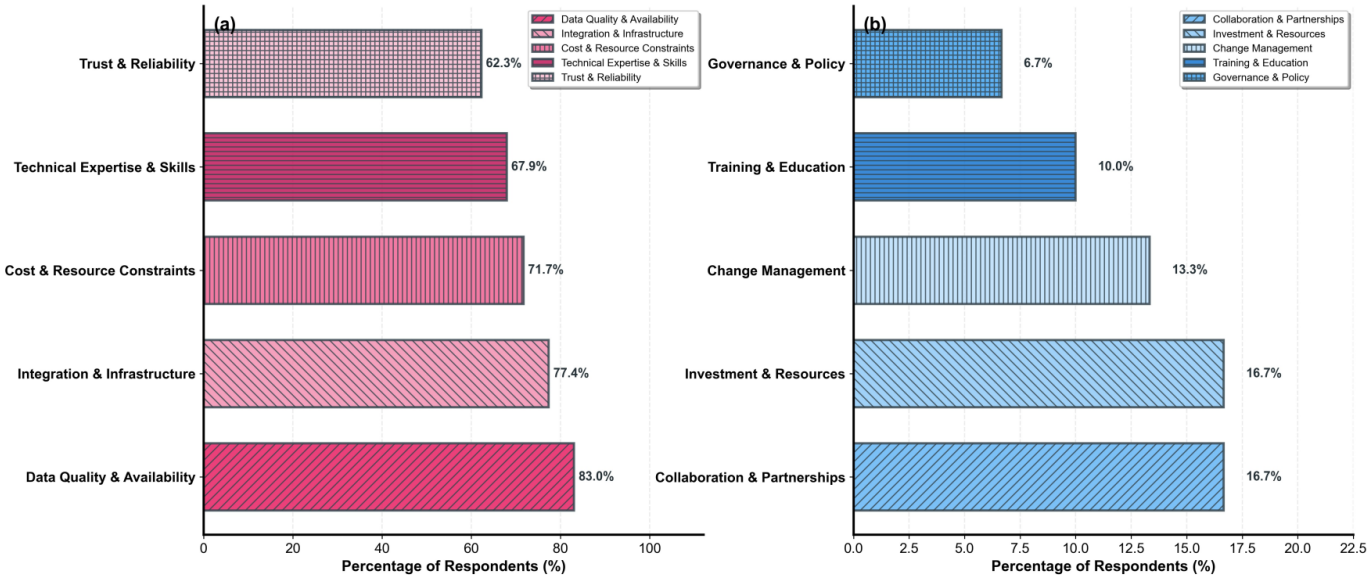
Figure 7: Word Cloud Visualization of Solution Strategies

DISCUSSION

The solution fragmentation paradox

The comparative analysis shows a clear asymmetry: obstacles exhibit a high concentration (with prevalence ranging from 43.4% to 83.0%), while solutions are scattered (with prevalence peaking at 16.7%). Figure 8 presents a side-by-side comparison of the key themes. This gap suggests that organizations have a more unified understanding of the challenges they face than they do of the most effective ways to address them, creating both challenges and opportunities for knowledge sharing and consolidation.

Figure 8: Comparative Thematic Analysis: (a) Implementation Obstacles; (b) Solution Strategies



The fragmentation observed can be attributed to several factors. Firstly, the implementation of artificial intelligence represents a highly complex organizational transformation, where universal solutions are rare. Secondly, the early stage of generative AI adoption means that best practices are still in their formative stages. Thirdly, articulating solutions demands a higher level of expertise compared to the relatively lower level of expertise required to identify the obstacles.

The data-infrastructure nexus

The strongest emerging pattern links data quality, infrastructure integration, and trust issues. Data Quality Availability (83.0%) and Integration Infrastructure (77.4%) were the most prominent, showing the need for simultaneous focus on data governance and infrastructure modernization.

However, responses related to solutions reveal a lack of a direct approach to this connection. Although Data Management (4 responses) emerged as a solution theme, it was significantly less emphasized than the prevalence of the associated barrier would suggest is necessary. This disconnect highlights potential gaps in solution development or an acknowledgment that data-infrastructure issues may not have easily applicable solutions.

The innovation challenge

A qualitative study on barriers established scepticism about the possibility of AI to transform business models and perceived constraints that need human decision-making to make strategic choices. Yet solution responses did not depict much activity in innovation enablement. The total lack of Pilot Projects & Testing as a solution theme is particularly striking, since the literature on innovation focuses on experimentation and fast prototyping.

The governance implementation gap

Quantitative results showed a high level of agreement that data governance, privacy, and security are important factors (82.69% agreement), and the same level of prioritisation was achieved with fairness and bias reduction (84.61% agreement). Nonetheless, solution responses based on qualitative solutions were slightly involved with Governance & Policy (6.7%, n=2). The lack of connection presents a governance paradox: stakeholders recognize the importance of governance but offer minimal description of governance mechanisms or structures.

IMPLICATIONS FOR PRACTICE

The analysis has a number of implications that can be applied to the contact-centre organisations:

1. **Prioritise Data Foundations:** The sheer amount of data quality issues (83.0%) and the high rate of co-occurrences necessitates the development of solid data governance, data quality assurance, and availability infrastructure before even starting to deploy AI.
2. **Embracing Implementation Strategies that are integrated:** When obstacles are interconnected as shown by extensive theme co-occurrences, cross-functional teams should be sought by organisations to undertake integrated strategies that cater to various dimensions at a time.
3. **Build Hybrid Expertise Models:** Due to talent constraints and cost limits, organisations must seek hybrid approaches which integrate internal capacity building through training, external capacity building through partnerships, and knowledge-capture systems.
4. Frame AI as Augmentation: Due to the continued focus on human judgment and AI complementary roles, effective change management needs to frame AI as a labor force aug-mentation and not replacement.
5. **Build Innovation Capabilities:** Determined innovation gaps need to be actively addressed, which means that experimentation, rapid prototyping, and psychological safety of productive failures should be encouraged, and mechanisms to systematically find transformative use cases should be established.
6. **Operationalise Governance:** Organisations must turn principles into tangible policies, allocate specific responsibilities, and entrench governance across lifecycles of implementation.

LIMITATIONS

There are a number of limitations of this study that should be mentioned. The size of the sample of solution strategies (N=30) is much smaller than the sample of obstacles (N=53), which could restrict the generalisability. Thematic coding was based on the use of keywords and was classified based on the keywords and this might not represent subtle semantic differences. The sample composition was biased towards the managerial levels (62 percent), which

may not reflect the views of the frontline. Cultural and linguistic differences in the Australasia region can also bring about response differences which are not exhaustively represented. Lastly, the responses are based on perceptions expressed and not organisational capabilities, which is prone to social desirability bias.

CONCLUSION

This qualitative study is an empirical demonstration of the complex nature of the issues that organisations encounter when adopting generative AI in contact-centre services. The fact that the majority of the issues are related to data quality issues (83.0%), integration difficulties (77.4%), and resource limitations (71.7%) will indicate that the complexity of the implementation is not limited to the technical aspect.

The disjointedness of solution strategies (maximum 16.7% prevalence) is an indicator of a new area where the best practices are still disputed and situation-specific. Organisations are forced to cope with this ambiguity by means of systematic testing, cross-sector knowledge and adaptive implementation frameworks that recognise the existence of interdependent systems of barriers.

The critical insights that have come out of this analysis are: (1) data and infrastructure issues are an integrated nexus which has to be given attention simultaneously; (2) the lack of expertise necessitates hybrid models between internal development and external partnerships; (3) innovation capabilities need to be intentionally cultivated and not just an operational efficiency focus; (4) governance has to shift towards an operationalised practice and not just an abstract principle.

To practitioners, this discussion highlights that effective implementation of generative AI demands organisational preparedness on a broad scale in terms of technical infrastructure, data governance, talent capabilities, cultural preparedness and governance structures. The findings show that organizations that treat AI implementation as a holistic change are better positioned for long-term success.

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Research Article

Strengthening Manufacturing Resilience: A Data-Driven Analysis of Key Supply Chain Enablers

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ABSTRACT

Manufacturing supply chains face growing risks from events such as pandemics and climate-related disruptions, making supply chain resilience (SCR) increasingly essential for business continuity and competitiveness. This study adopts a quantitative research approach to examine the factors influencing SCR, drawing on a large dataset of manufacturing firms. Grounded in the dynamic capability view, the analysis focuses on key variables, such as supplier collaboration, lead time, transportation cost efficiency, supply chain complexity, and SCM practices. Using a combination of statistical techniques, including t-tests, ANOVA, correlation, and regression analysis, the study finds that stronger supplier collaboration and more efficient transportation significantly enhance resilience, while longer and more variable lead times reduce it. Notably, well-managed supply chain complexity also contributes positively to SCR. The findings advance theory by linking operational metrics to dynamic capabilities and offer practical guidance for improving resilience through logistics optimisation, collaboration, and data-driven planning. Overall, the research highlights SCR as a measurable and strategic capability essential for sustaining manufacturing performance in uncertain environments.

Keywords: Supply chain resilience, *Manufacturing*, *Data analytics*, *Dynamic capabilities*, *Supplier collaboration*

INTRODUCTION

Manufacturing is the backbone of the global economy, driving technological innovation, employment, and global trade. According to the United Nations Industrial Development Organisation (2024), manufacturing accounted for around 20% of the world's gross domestic product (GDP) in 2024. The key economic role of the sector was demonstrated by the industry's roughly 40% share of the GDP in China, which was much higher than the worldwide average (ChinaPower, 2023). However, several incidents, such as the COVID-19 pandemic and unprecedented climate-related disruptions, have shown how vulnerable the global industrial supply chain is (Khanzad & Gooyabadi, 2021; Um & Han, 2020). These disruptions promote the industrial demand for supply chain resilience (SDR). SCR has been scholarly defined as the ability to anticipate, absorb, and recover from disruptions while maintaining acceptable performance levels, and it has emerged as a critical performance metric (Loh & Tan, 2024). ElKhouly et al. (2020) suggested that strong SDR is essential for manufacturing companies that compete in turbulent markets to ensure production continuity, maintain competitiveness, and meet stakeholder expectations. The rise of Industry 4.0 technologies has greatly expanded the application opportunities of data analytics in the manufacturing industry (Saad et al., 2023). Manufacturers can systematically collect, integrate, and interpret vast amounts of data, effectively applying data analytics to maintain a competitive advantage (Pinochet et al., 2021). Decisions supported by data analytics are often timelier and more accurate, helping manufacturers optimise management decisions, enhance their ability to cope with uncertainty, and strengthen resilience (Kamble & Gunasekaran, 2020; Thirathon et al., 2022).

In the manufacturing sector, SCR is especially crucial since it helps manufacturers maintain operations and recover quickly from shocks (Ivanov & Dolgui, 2020). Particularly for the internationally interconnected manufacturers, SCR has transformed from a reactive measure to a strategic competence, guaranteeing long-term performance under uncertainty (Pettit et al., 2019; Tarigan et al., 2021). By employing a quantitative research approach, the objectives of this paper are to 1) identify the key factors that affect SCR and 2) put forward targeted recommendations to help manufacturers cope with challenges and support decision-making.

LITERATURE REVIEW

Supply Chain Resilience

SCR is widely considered a key capability for businesses to withstand and recover from interruptions while maintaining continuity. The common definition of SCR is the ability to anticipate, absorb, and recover from unfavorable events while maintaining acceptable performance levels (Loh & Tan, 2024; Wu et al., 2024). Zhou et al. (2024) categorise SCR into internal and external types, noting their differing emphases on threat mitigation. However, the scope and emphasis of SCR vary considerably across studies. For example, Um and Han (2021) conceptualise resilience as a dynamic capability that enables firms to reconfigure resources proactively, whereas Mwangola (2018) views resilience as a reactive capacity for recovery. This divergence reflects ongoing debates about whether resilience should be regarded primarily as an adaptive, proactive competence or as a set of reactive practices.

Many scholars have stressed the importance of effective supply chain management (SCM) for businesses in the manufacturing sector. Selepe and Makinde (2024) suggested that poor supply chain quality may cost manufacturing companies up to 55% of total product costs. SCR is a crucial criterion for assessing SCM as it improves the capacity to continue operating in the face of interruptions while advancing important SCM goals. SCR is an integrated capacity inside SCM that improves operational continuity, agility, and flexibility rather than existing as a stand-alone idea (Loh & Tan, 2024). SCM tactics, including supplier cooperation, internal integration, and visibility, are also now commonly acknowledged as key components of SCR (Asamoah et al., 2020; Zhou et al., 2024). Hussain et al. (2022) claim SCR promotes adaptability and proactive risk management in SCM. SCM activities, such as procurement, sourcing, logistics, and production, rely on a resilient infrastructure to mitigate risk and recover from disruptions (Tarigan et al., 2021; Wu et al., 2024). Businesses with strong SCM frameworks, supported by real-time data, a large supplier base, and backup plans, for example, were able to maintain service levels in the face of systemic shocks during the COVID-19 pandemic (Ivanov & Dolgui, 2020). Thus, developing SCR is essential for long-term competitiveness as well as reducing supply chain risks for manufacturers.

This study draws on the dynamic capabilities perspective, which explains how firms sustain competitiveness in turbulent environments through their capacity to a) sense opportunities and threats, b) seize them through timely resource commitments, and c) transform their structures and processes to remain aligned with changing conditions (Teece, 2007). Within this framework, SDR can be interpreted as an outcome of dynamic capabilities, as resilient firms continually sense potential disruptions, seize appropriate response options, and transform operational routines to maintain continuity. The concept of adaptive capacity captures the ability of organisations and supply chains to adjust, reorganise, and evolve when confronted with stress and uncertainty (Folke et al., 2010). Adaptive capacity represents the practical manifestation of dynamic capabilities by shaping how quickly and effectively firms adjust their operations. Accordingly, the factors examined in this study, such as supplier collaboration, digitalisation, internal

integration, organisational culture, sustainability practices, and supply chain complexity, are viewed as enablers of adaptive capacity that reflect underlying dynamic capabilities driving resilience outcomes.

Key Enablers of SCR

Several enablers of SCR have been highlighted in prior studies. Supplier collaboration is one of the most frequently cited drivers of resilience, as close and transparent relationships with suppliers build trust, facilitate information sharing, and support joint problem-solving. These relational mechanisms enable firms to respond more quickly and effectively when facing disruptions, reducing recovery time and stabilising operations (Asamoah et al., 2020). Digitalisation and IT capabilities also represent a critical determinant of resilience. Emerging technologies, such as artificial intelligence, blockchain, and big data analytics, provide firms with advanced decision-making tools, predictive models, and real-time monitoring capabilities (Lin & Karia, 2024; Taha et al., 2025). This allows them to anticipate risks, detect early warning signals, and allocate resources more effectively during crises (Taha et al., 2025) . In addition, internal integration strengthens resilience by fostering coordination and information flow across functional departments. High levels of integration reduce silos, streamline processes, and enable more coherent decision-making, thereby enhancing the organisation's ability to adapt to changing circumstances (Tarigan et al., 2021).

Beyond these operational enablers, organisational and strategic orientations also shape resilience. Organisational culture has been identified as a determinant of SCR, since the effectiveness of technology adoption depends on cultural values that encourage openness, adaptability, and learning. Without complementary organisational and cultural changes, new technologies may fail to translate into greater resilience (Gani et al., 2022; Shah et al., 2023). Similarly, sustainability-oriented management practices, including those aligned with environmental, social, and governance (ESG) principles, enhance resilience by reinforcing stakeholder trust, building social capital, and promoting long-term cohesion across supply chain partners (Wu et al., 2024). Another determinant is supply chain complexity (SCC), defined as the degree to which supply chains are composed of numerous and diverse elements that interact in unpredictable ways (Akin, 2022; Bode & Wagner, 2015; Bozarth et al., 2009). Complexity can manifest in large and diverse supplier bases, heterogeneous internal processes, or varied customer requirements, each of which increases uncertainty and coordination challenges. However, SCC can also enhance resilience by providing redundancy, access to diverse knowledge resources, and greater adaptive capacity (Akin, 2022).

Digital Technologies for Data Analytics in SCR

The application of technology for data analytics in SCR research has expanded in recent years, with various methods employed to investigate resilience drivers and outcomes. In the past decade, digitalisation has consistently emerged as a key development trend for industrial SCM (Liu & Chiu, 2021). Supply Chain 4.0 can be seen as the application of the Industry 4.0 concept, providing the foundation and data support for the digital SCM (Lin & Karia, 2024; Liu & Chiu, 2021). Emerging digital technologies, including AI, big data, blockchain, and digital twins, have also been integrated into SCR research, supporting quick decision-making (Shah et al., 2023; Taha et al., 2025). Big data analytics is a collection of data, analytical tools, computer algorithms, and techniques to derive meaningful insights and patterns from large industrial datasets (Kamble & Gunasekaran, 2020). Some scholars have even defined supply chain digitalisation as technology that integrates all supply chain functions of manufacturing to improve decision-making and management levels (Lin & Karia, 2024). Companies that are unprepared to capture these digital and technological advancements are likely to be left behind (Bai et al., 2020). In summary, digital technologies help industrial enterprises capture large amounts of real data in the supply chain, providing a solid foundation and foundation for

data-driven resilience strategies.

Recent studies have applied a variety of data analytics methods to investigate SCR. Descriptive and diagnostic approaches have been used to summarise resilience characteristics and explore correlations between variables (Mahira, Santosa, et al., 2023), while regression analysis has examined the effects of factors such as integration, collaboration, and risk exposure (Huang et al., 2023; Hussain et al., 2022). Prescriptive methods have also been employed to classify firms into different resilience profiles (Um & Han, 2020; Wu et al., 2024). While these approaches provide useful insights, most remain focused on single aspects of resilience or rely on limited case-based evidence. What is still lacking is large-scale empirical research that systematically evaluates multiple operational determinants of resilience in an integrated framework. This study addresses that gap by applying various statistical techniques to a large-scale dataset of manufacturing firms, in order to offer systematic and generalisable evidence on the drivers of supply chain resilience.

METHODOLOGY

To examine factors influencing SCR, this study conducted various quantitative analyses on a real-world supply chain dataset from 999 leading manufacturing companies (Kaggle, 2024). SCR is a key factor influencing SCM and has a significant impact on operational performance for companies (Alkhatib & Momani, 2023; Budwal, 2022). In the manufacturing industry, companies are increasingly relying on intelligent systems and digital tools to improve the SCR (Rizki et al., 2022). Using authentic industry data enables the study of SCR in a realistic context, as recommended by (Um & Han, 2020). The dataset categorises companies based on implemented SCM strategies such as Just-In-Time, Cross-Docking. The dataset is also structured with both categorical and numerical variables, which enables comprehensive use of descriptive, diagnostic and predictive analytics to capture essential indicators relevant to SCR, including supplier lead time variability, collaboration levels, and transportation cost efficiency. The key variables of this dataset analysed were summarised in Table 1.

These approaches align with recent methodological recommendations to be based on real-world industry data analytics rather than hypothetical or simulated scenarios (Condon et al., 2023; Mahira, Santosa, et al., 2023). The dataset reflects consolidated records from actual firms and provides a credible foundation for analysing resilience in the manufacturing sector.

The Preparation for Data Analytics

To ensure data quality and consistency, data preparation is necessary for data analytics. The data cleaning process is the first step of the overall analytical approach of this report. Data cleaning is a critical stage in the data analytics process, as poor-quality data can lead to misleading results, unreliable patterns, and biased conclusions, including a) handling missing values, b) detecting and addressing outliers, and c) standardising data formats (Rahm, Do, et al., 2000). Research has shown that following established cleaning procedures ensures that downstream analyses are based on consistent and reliable inputs (Elmobark, 2024). These cleaning steps can improve the reliability and validity of subsequent statistical procedures (Mahira, Santosa, et al., 2023).

Justification of Relevant Variables for SCR

Variables related to SCR were carefully selected following initial data preparation and informed by theoretical support. Drawing on the dynamic capability view and incorporating relevant literature (e.g., Teece, 2007; Zhou et al., 2024), this study identified supplier collaboration, SCM practices, lead time, transportation, and supply chain complexity

Table 1: Key Variables of the Dataset

NO.	Variable	Description	Datatype
1	SCM Practices	Supply Chain Management strategy adopted	Categorical
2	Supplier Count	Number of suppliers used	Numerical
3	Lead Time (days)	Average time taken to receive supplies	Numerical
4	Customer Satisfaction (%)	Customer satisfaction rating	Numerical
5	Supplier Lead Time Variability (days	Variability in lead time across suppliers	Numerical
6	Transportation Cost Efficiency (%)	Efficiency in transportation costs	Numerical
7	Supply Chain Complexity Index	Complexity level of the supply chain	Categorical
8	Supplier Collaboration Level	Level of collaboration with suppliers	Categorical
9	Supply Chain Resilience Score	Score indicating the resilience of the supply chain	Numerical

as core factors of SCR. For example, supplier relationships reflect the dynamic capabilities of the external supply chain, while transportation efficiency influences the responsiveness of the entire supply chain and is also the most susceptible to disruptions. Lead time factors reflect the timeliness of the supply chain. Therefore, this selection of variables reflects both operational realities and the theoretical conception of SCR as a dynamic strategic capability.

Variable selection is also based on literary support. Supplier collaboration enhances information exchange and adaptive capacity (Issah et al., 2024) Key components of SCR are flexibility and recovery capabilities, enhanced by the application of SCM (Loh & Tan, 2024). The overall SCR can be negatively impacted by longer supplier lead times, which can make it more difficult to absorb and bounce back from disruptions (Chang & Lin, 2019). Transportation can significantly enhance a supply chain's ability to quickly respond to disruptions and recover effectively (Ambra et al., 2024). The complexity of supply chains significantly affects SCR and can be regulated through big data analytics capabilities and organisational adaptability (Iftikhar et al., 2023). According to Gani et al. (2022), these factors are consistent with current empirical research that links to improved resilience performance in industrial environments. A strong analytical basis for evaluating SCR is provided by these factors taken together, which capture the firm's capacity to perceive, adjust, and react to disturbances (Asamoah et al., 2020; Zhou et al., 2024).

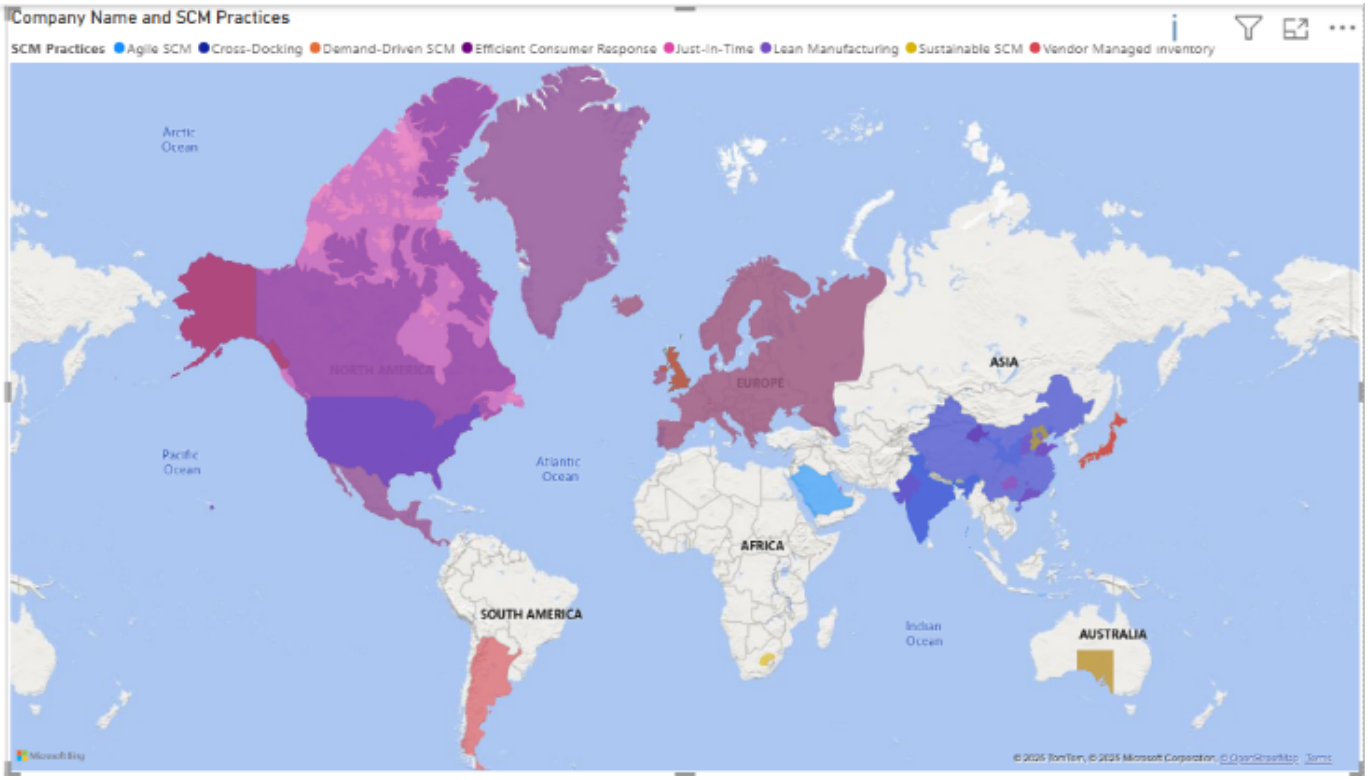
After identifying relevant variables, appropriate data analytics methods were defined. This structured approach ensured the validity of the analysis and provided reliable insights and actionable recommendations for manufacturing companies. The full data preparation, selection workflow and the data analytics process are summarised in Figure 1. This visual representation provides a clear outline and framework for the report.

The Visualisation for the Dataset

The manufacturing companies in this dataset use different SCM strategies. Figure 1 illustrates the widespread adop-

tion of diverse SCM practices, particularly in developed countries, highlighting a clear global trend toward supply chain digitalisation. China stands out for its diversified implementation of multiple practices.

Figure 1: World map of manufacturers practising SCM



Data Analytical Techniques

The data analytics focused on exploring the determinants of SCR in the industrial sector, applying a variety of analytical methods to enhance the depth and comprehensiveness of the findings. When dealing with critical business data, the proper analytical methods are crucial to conclusions and results (Condon et al., 2023). ANOVA and linear regression are used for this data problem to examine the relationships between SCR and its potential drivers. Descriptive analytics provide an overview of the data distribution and initial patterns, can visualise relevant data and express differences more intuitively and establish a strong foundation for deeper analysis (Gunasekaran et al., 2017), while diagnostic testing highlights performance gaps that firms must address (Condon et al., 2023). Each method was selected for its specific strengths. However, the reliance on secondary data constrained the customisation of variables and may have introduced measurement bias. Combining the different methods for analysis builds a comprehensive and reliable evaluation framework.

Figure 2: Procedures

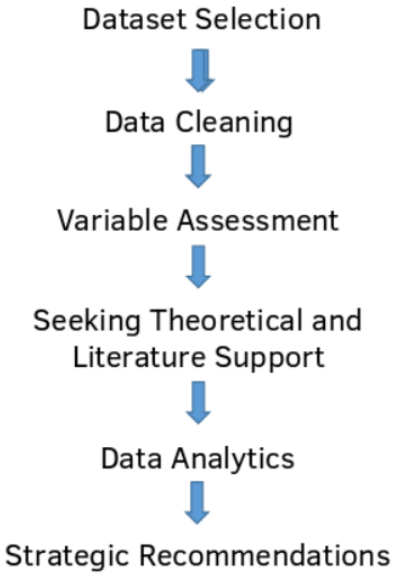
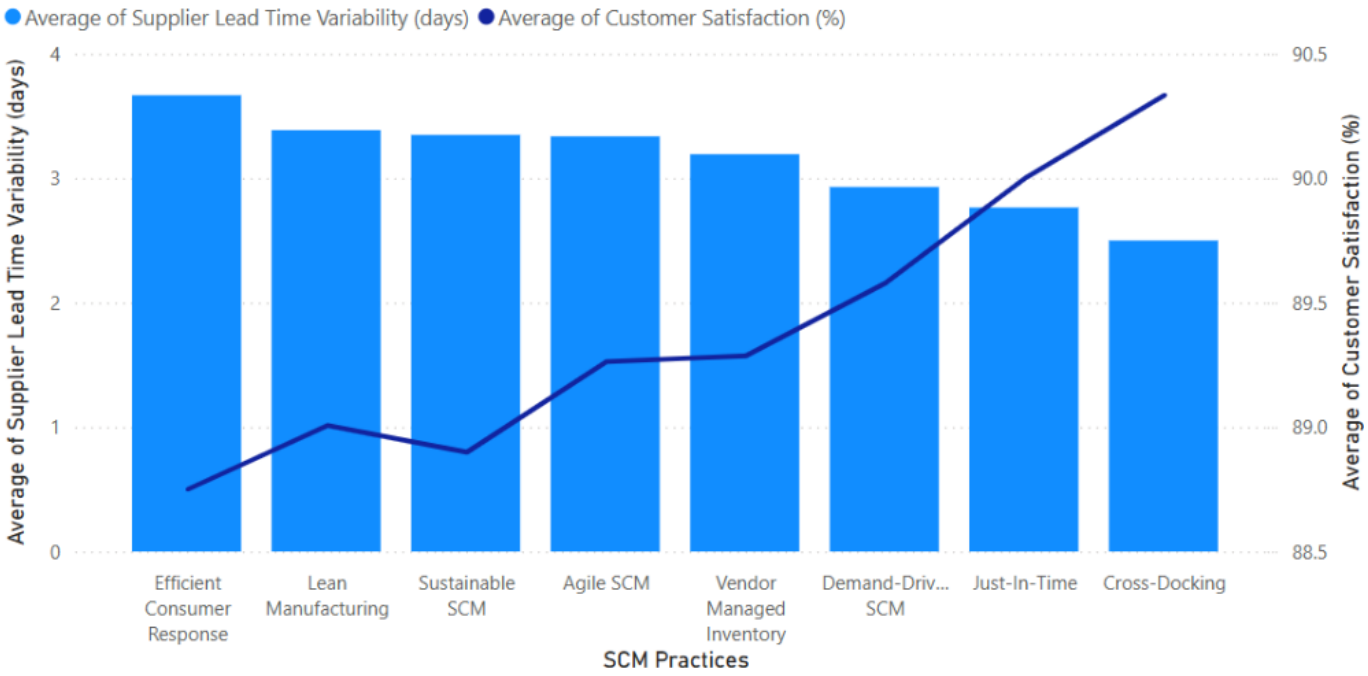


Figure 3 shows that different SCM practices have different delivery variability times, among which cross-docking has the lowest average variability and the

highest customer satisfaction. This shows that the smaller the variation in the lead cycle, the higher the customer satisfaction.

Figure 3: Impact of SCM Practices on Supplier Lead Time Variability and Customer Satisfaction



RESULTS

Descriptive and Diagnostic Analytics

The *t*-test is one of the commonly used analytical techniques in diagnostic analytics (Condon et al., 2023). The result of the t-test of supplier collaboration level and SCR is seen in Table 2 and Figure 4. The mean is a key number in descriptive analytics (Condon et al., 2023). Firms with high supplier collaboration reported a significantly higher resilience score (M = 89.5) compared to medium collaboration (M = 84.92). The t-test confirms a significant difference between them ($p < 0.01$). This indicates that supplier partnerships substantially enhance SCR.

The ANOVA test is also one of the commonly used analytical techniques in diagnostic analytics (Condon et al., 2023). The result of the ANOVA test between supply chain complexity and SCR is shown in Table 3. Firms with high complexity showed the highest average resilience score (M = 91.38), followed by low (M = 88.44) and medium complexity groups (M = 86.66). ANOVA results confirm a significant difference among the groups, suggesting that increased complexity, when properly managed, can enhance resilience capabilities ($F = 428.56$, $p < 0.01$).

The result of the ANOVA test of SCM practice on SCR is shown in Table 4 and Figure 5. Results reveal significant differences in resilience scores across various SCM practices ($p < 0.05$). While the overall means are relatively close, practices like Just-In-Time (M = 89.26) and Cross-Docking (M = 88.94) show slightly higher resilience compared to others. The findings suggest that SCM choices can influence SCR.

The result of the correlation test between various variables and SCR is shown in Table 5. The result reveals that lead time ($r = -0.72$) and supplier lead time variability ($r = -0.76$) have fairly strong negative influences on resilience

scores. Additionally, Transportation Cost Efficiency (r = 0.81) shows a very strong positive relationship with resilience.

Table 2: SCR by Supplier Collaboration Levels: t-Test: Two-Sample Assuming Equal Variances

	High	*Medium*
Mean	89.545322	84.9238095
Variance	4.5996999	1.29353958
Observations	684	315
Pooled Variance	3.5584418	
Hypothesised Mean Difference	0	
df	997	
t Stat	35.979469	
P(T<=t) one-tail	1.13E-182	
t Critical one-tail	1.6463834	
P(T<=t) two-tail	2.26E-182	
t Critical two-tail	1.9623462	

Figure 4: Average SCR by Supplier Collaboration Levels

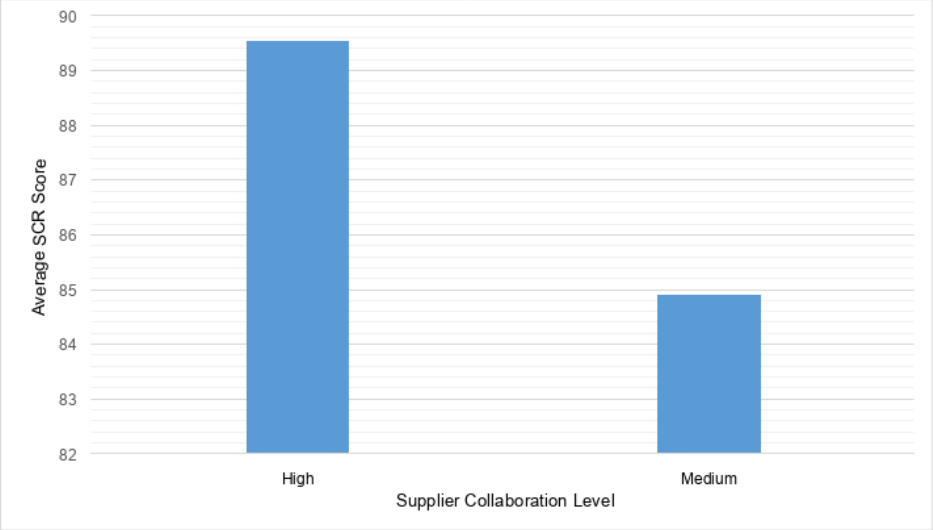


Table 3: ANOVA Test between Supply Chain Complexity and SCR: Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High	236	21565	91.37712	4.2444104
Medium	586	50782	86.6587	4.9226335
Low	177	15653	88.43503	2.8721751

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3771.568	2	1885.784	428.55994	5.2E-135	3.004761
Within Groups	4382.68	996	4.400281			
Total	8154.248	998				

Table 4: The ANOVA test of SCM Practice on SCR: Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Agile SCM	312	27572	88.37179	9.192514
Cross-Docking	18	1601	88.94444	2.879085
Demand-Driven SCM	57	5036	88.35088	6.053258
Efficient Consumer Response	12	1056	88	3.636364
Just-In-Time	34	3035	89.26471	9.230838
Lean Manufacturing	326	28586	87.68712	7.895649
Sustainable SCM	69	6065	87.89855	9.563086
Vendor Managed Inventory	171	15049	88.00585	7.064671

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	145.462	7	20.78029	2.571334	0.01251	2.018803
Within Groups	8008.786	991	8.08152			
Total	8154.248	998				

Figure 5: Average SCR by SCM Practice Types

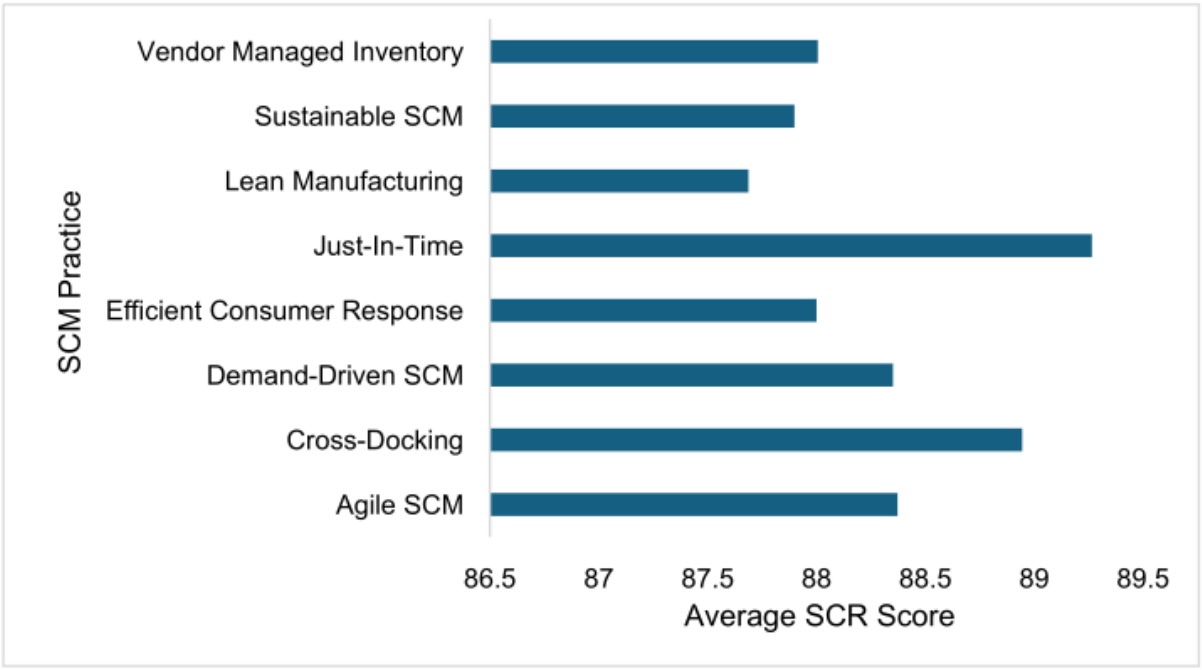


Table 5: Correlation Test between Different Variables and SCR

	Lead Time (days)	*Supplier Lead Time Variability (days)*	*Transportation Cost Efficiency (%)*	*Supply Chain Resilience Score*
Lead Time (days)	1			
Supplier Lead Time Variability (days)	0.804311956	1		
Transportation Cost Efficiency (%)	-0.647150697	-0.788143055	1	
Supply Chain Resilience Score	-0.721586796	-0.755917006	0.809356194	1

Predictive Analytics

Correlation test reveals associations, which cannot lead to causal inferences (Gershman & Ullman, 2023). Therefore, regression analysis provides a more reliable approach to uncover potential causal structures (Chang & Lin, 2019; Li et al., 2023) found through multi-level simulation that extending the delivery time will reduce the recovery speed and crisis response capabilities. Budwal (2022) emphasised that SCR can not only reduce risk exposure but also improve customer satisfaction. Therefore, using resilience as a dependent variable and lead factors as independent variables for regression analysis can help companies fully understand the adaptability and recovery potential in complex supply chain networks. The result of linear regression analysis is shown in Tables 6 - 7 and Figures 6 - 7.

Table 6: Linear Regression for Lead Time and SCR

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.721586796
R Square	0.520687503
Adjusted R Square	0.520206749
Standard Error	1.979947895
Observations	999

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4245.815163	4245.815	1083.063	2.149E-161
Residual	997	3908.433085	3.920194		
Total	998	8154.248248			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	93.70504534	0.181809426	515.4026	0
Lead Time (days)	-0.490587541	0.014906982	-32.9099	2.1E-161

	Lower 95%	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	93.3482723	94.06181838	93.3482723	94.0618184
Lead Time (days)	-0.519840201	-0.46133488	-0.5198402	-0.4613349

Table 7: Linear Regression for Supplier Lead Time Variability and SCR

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.755917006
R Square	0.57141052
Adjusted R Square	0.570980641
Standard Error	1.872255601
Observations	999

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4659.423234	4659.423	1329.235	1.2485E-185
Residual	997	3494.825014	3.505341		
Total	998	8154.248248			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	92.5370374	0.135644677	682.2018	0
Supplier Lead Time Variability (days)	-1.358343633	0.037257071	-36.4587	1.2E-185

	Lower 95%	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	92.27085558	92.803219	92.27085558	92.8032192
Supplier Lead Time Variability (days)	-1.43145491	-1.285232	-1.43145491	-1.2852324

Linear regression results indicate that both Lead time and Supplier lead time variability have significant negative impacts on SCR. The models yield high explanatory power, with R^2 values of 0.52 and 0.57, meaning over half of the variance in resilience scores is explained by these variables. The F-statistics (F = 1083.06; F = 1329.24, $p < 0.01$) confirm that the models are significant overall. Specifically, each day of added lead time reduced resilience by 0.49 points (β = −0.491), and variability had an even stronger effect (β = −1.36). These correlation tests and linear regression results show that both lead time and supplier lead time variability have similar effects on SCR in the one dataset, indicating that it is not surprising that lead time factors are a key determinant of SCR and demonstrating the reliability of the dataset.

The scatter plots illustrate a clear negative linear relationship between lead factors and SCR. These visuals reinforce regression results, highlighting that delivery consistency (low variability) has an even stronger impact on resilience than speed alone. Predictive analytics enables robust causal inference and future-oriented decision-making (Li et al., 2023) that overcomes the ambiguity of correlational insights (Gershman & Ullman, 2023).

A separate linear regression analysis was conducted for transportation cost efficiency. The result is shown in Table

8 and Figure 8. The result showed that transportation cost has a strong positive impact on SCR ($p < 0.01$). The blue diamonds in the line fit plot represent the actual observed values, while the orange squares indicate the predicted values from the regression model. The close alignment between the actual and predicted points suggests a strong linear relationship, confirming the high R^2 value (0.655) from the regression output. As transportation cost efficiency increases, SCR also rises, supporting the regression findings.

Figure 6: Scatter Plot of Lead Time

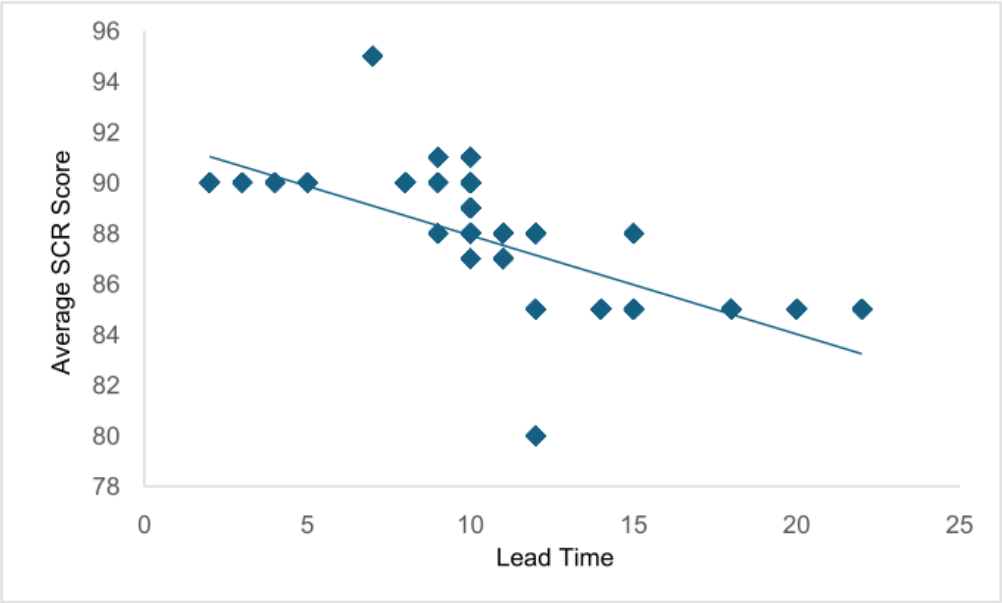


Figure 7: Scatter Plot of Supplier Lead Time Variability

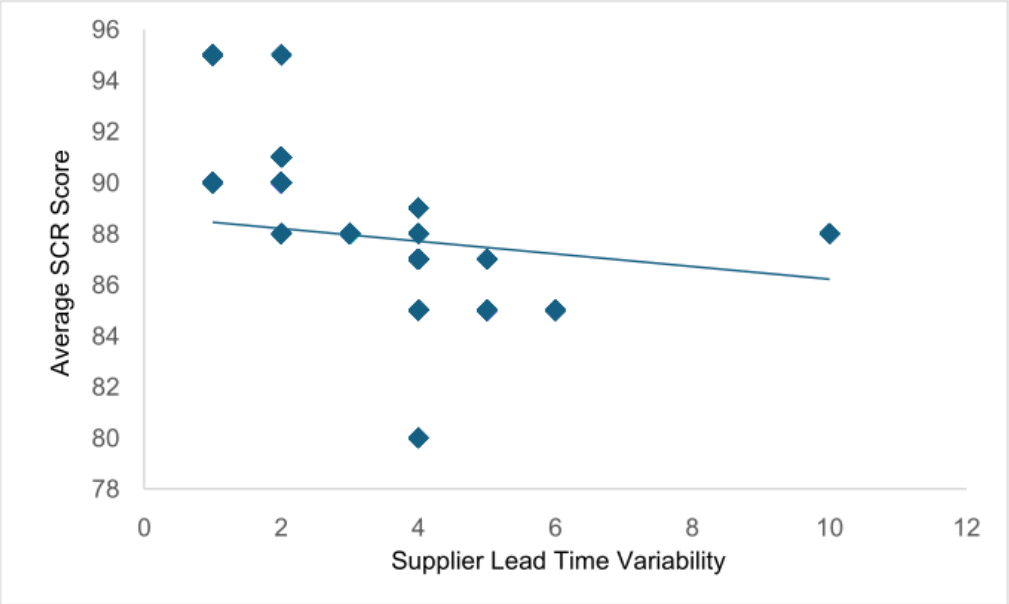


Table 8: Linear Regression Analysis Between Transportation Cost Efficiency and SCR

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.80935619
R Square	0.65505745
Adjusted R Square	0.65471147
Standard Error	1.67964604
Observations	999

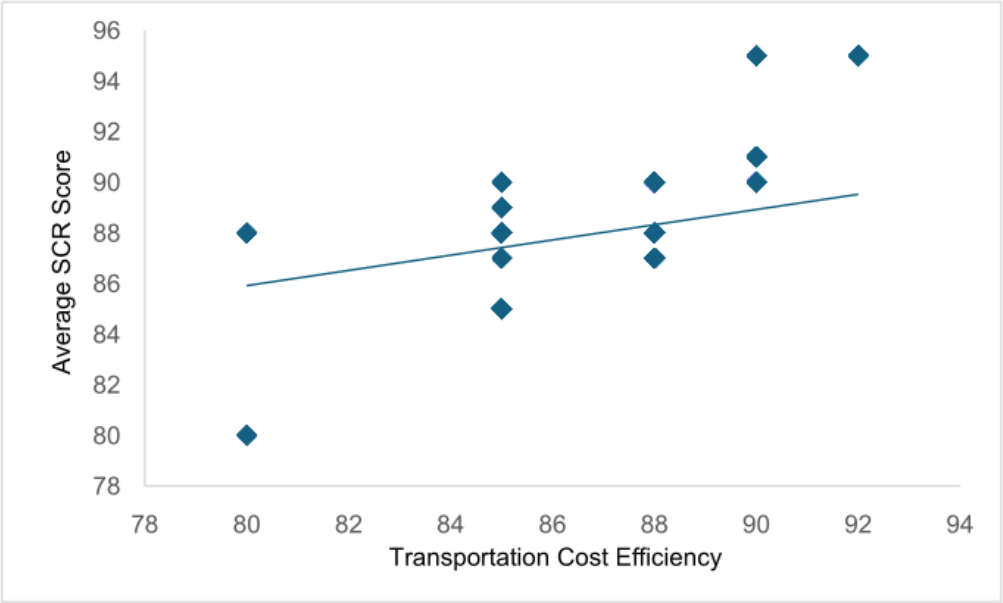
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5341.50105	5341.50105	1893.336	1.15E-232
Residual	997	2812.74719	2.82121083		
Total	998	8154.24825			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	3.33594871	1.94849081	1.71206797	0.087195
Transportation Cost Efficiency (%)	0.97247298	0.02234929	43.5124852	1.2E-232

	Lower 95%	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.4876649	7.159562	-0.4876649	7.1595623
Transportation Cost Efficiency (%)	0.92861594	1.01633	0.928615939	1.01633

Figure 8: Scatter Plot of Transport Cost Efficiency



DISCUSSION

This study identifies several findings and statistically significant factors that influence SCR in the industrial sector. Through descriptive and diagnostic analytics, supplier collaboration was found to have a strong positive association with resilience scores, while longer lead time and greater lead time variability were consistently linked to lower SCR. These associations were supported by predictive analytics, which showed that resilience declined measurably with each additional day of lead time. In particular, demand unpredictability and variability in supply deliveries were shown to have especially detrimental impacts, as they amplify the bullwhip effect and disrupt production schedules. On the other hand, supplier cooperation and transportation cost efficiency demonstrated a strong positive correlation with SCR, suggesting that logistics optimisation tools such as AI-based routing, real-time tracking with IoT sensors, and predictive inventory systems are essential to resilience building. This also reinforces the dynamic capability view, which holds that inter-organisational partnerships and advanced digitisation strengthen a firm's capacity to sense disruptions, reallocate resources, and maintain continuity in turbulent environments (Zhou et al., 2024).

While supply chain complexity has traditionally been viewed as a risk factor, recent studies suggest that well-managed complexity can also enhance resilience by increasing flexibility and resource redundancy, particularly in high-performing firms (Iftikhar et al., 2023). The findings here are consistent with prior work showing that unmanaged complexity impairs adaptive capacity by reducing visibility and coordination (Tarigan et al., 2021). At the same time, complexity can strengthen adaptive capacity when supported by mechanisms such as supplier diversification, flexible production systems, and digital platforms that integrate real-time data across tiers. These results also confirm that different SCM practices, including collaboration, integration, and sustainability initiatives, contribute jointly to SCR rather than in isolation. The findings validate the importance of these key enablers and emphasise that resilience emerges from the interaction of multiple factors, such as collaboration, logistics efficiency, digitalisation, and complexity management, rather than from any single determinant. Future research should therefore examine additional factors not captured by this dataset, such as organisational culture, regulatory frameworks, and industry-specific

policies, which are likely to further shape how firms build and sustain resilience.

This study also provides implications for firms in the manufacturing industry from two specific aspects. From a practical perspective, the findings offer several recommendations for industrial firms seeking to strengthen their supply chain resilience. Firms should prioritise efforts to reduce lead time variability through improved demand forecasting, supplier performance monitoring, and process standardisation. At the same time, investing in supplier collaboration by fostering transparency, joint problem-solving, and information sharing can enhance responsiveness and flexibility during disruptions. High levels of collaboration are not only associated with greater resilience but also support long-term risk mitigation (Gershman & Ullman, 2023; Issah et al., 2024). In addition, improving transportation cost efficiency plays a vital role in supply chain resilience. Companies should adopt logistics optimisation tools and route planning algorithms to manage costs while maintaining service levels. Managers are also encouraged to adopt data analytics as an ongoing tool for resilience assessment and decision-making rather than a one-off exercise. Future research should build on these insights by applying longitudinal designs and mixed methods approaches to capture the dynamic evolution of resilience and to test interventions aimed at improving supply chain performance in uncertain environments for manufacturing companies.

From a management perspective, this study suggests that enhancing SCR requires an integrated approach. As multiple studies have demonstrated, SCM is increasingly digitalised, and managers should prioritise investments in emerging technologies (e.g., AI and blockchain technology) and equipment to stay current. Beyond stabilising lead time processes and reducing delivery variability, firms should invest in supplier development programmes, implement real-time monitoring systems, and standardise inbound logistics to mitigate upstream uncertainties (Ambra et al., 2024; Chang & Lin, 2019). Supplier collaboration should move beyond contractual coordination to joint risk assessment, shared contingency planning, and digital information sharing (Issah et al., 2024). Transportation cost efficiency, strongly associated with SCR, can be improved through AI-based route optimisation and predictive maintenance tools (Li et al., 2023). Managers must also recognise that resilience is shaped by complex interactions across technological, structural, and relational domains. Hence, resilience initiatives should align with organisational culture, ESG goals, and regulatory expectations (Wu et al., 2024). Instead of viewing SCR as a single performance metric, industrial firms should treat it as a strategic capability requiring long-term investment and cross-functional integration. Future policies must embed resilience into both operations and strategic planning frameworks. **CONCLUSION**

Using a real-world dataset of manufacturing companies, this study applied descriptive, diagnostic, and predictive analytics to investigate the factors that influence SCR in the industrial sector. The findings indicate that lead time and its unpredictability have a detrimental impact on resilience, but supplier cooperation and the economy of transportation are powerful facilitators. These results support earlier literature claims about how inter-organisational collaborations and operational stability contribute to resilience (Tarigan et al., 2021; Zhou et al., 2024). These results are conceptually based on the dynamic capability view, which defines resilience as a firm's ability to recognise risks, grasp opportunities, and reallocate resources in reaction to disturbance (Teece, 2007), supporting operational insights. The study contributes to SCR research by demonstrating how measurable supply chain practices map onto these dynamic capabilities, providing both theoretical and practical value. From a management perspective, the findings offer clear strategies for improving resilience through supplier engagement, logistics optimisation, and real-time monitoring. Nevertheless, the modest explanatory power of regression models suggests that other factors, such as digital maturity or regulatory conditions, may also play important roles. Future research should adopt longitudinal and multi-level approaches to capture the evolving and context-specific nature of SCR and better understand how

different capability configurations shape resilience across industrial environments.

This study also has several limitations. First, the use of cross-sectional data restricts our understanding of how SCR capabilities evolve over time, particularly under conditions of frequent or prolonged disruptions. Second, the analysis did not examine the potential interaction effects among determinants or the moderating influence of contextual variables such as organisational culture or ESG governance, both of which may play important roles in fostering resilience (Wu et al., 2024). Third, we did not test the combined effects of these determinants on SCR using multiple regression or other advanced analytical methods (e.g., structural equation modeling and hierarchical regression), which could provide deeper insights into their joint influence. In addition, the absence of contextual segmentation across industries or regulatory regimes constrains the explanatory depth of the dataset. Despite these limitations, the application of data analysis techniques has produced valuable findings consistent with the dynamic capability view (Teece, 2007). To advance this line of research, future studies should employ longitudinal and multi-level designs to capture the dynamic development of resilience, while also adopting prescriptive analytics to generate insights tailored to different types of enterprises.

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Research Article

The Impact of Poor Documentation and Time Management on Construction Waste and Efficiency

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ABSTRACT

Inefficiencies in paperwork, time management, rework, and design processes during the design and planning phases significantly impact construction projects, leading to increased waste and reduced project efficiency. This research has investigated how these factors contribute to waste, focusing on errors, omissions/lack of information and poor-quality documentation, delays in decision-making, lack of clear communications and design-related issues that affect overall project outcomes. Employing a mixed-methods approach, the study has combined primary data from surveys with construction professionals, project managers, and designers, alongside secondary data from industry reports and academic literature on construction waste and project management. The research has identified critical inefficiencies in the design and planning phases that lead to increased waste, such as inaccuracies in project documentation, extended approval times, lack of waste minimization considerations in the design phase and frequent design revisions. These inefficiencies are expected to cause cascading effects throughout the project lifecycle, including unnecessary material handling, rework, and delays. The study has also explored opportunities for improvement by examining enhanced documentation practices, better time management, and more effective design coordination. Additionally, it investigated the benefits of adopting digital tools for accurate documentation, implementing more efficient scheduling techniques, and improving design-for-construction approaches to minimize rework. Therefore, the primary goal of this research was to investigate and identify inefficiencies in order to streamline the design and planning phases, reduce waste, and enhance project efficiency, thereby contributing to more sustainable and cost-effective construction practices in New Zealand.

Keywords: Construction waste, Time management, Project documentation. Rework in construction, Design inefficiencies

INTRODUCTION

The construction industry has been identified as one of the significant contributors to overall waste generation, and it has affected both environmental sustainability and overall project efficiency (Khuc et al., 2025). Apart from the usual material waste produced during construction projects, there is also substantial waste resulting from ineffective procedures, design flaws, and inadequate management techniques. If the construction waste factors are identified and tackled during the design phase, there are fewer chances of overall waste generation on site and loss due to time delays and incorrect work. The construction sector is essential for progressing contemporary infrastructure and economic advancement (Fei et al., 2021). Recent studies have shown that persistent issues such as inadequate documentation, design flaws, communication breakdowns, and poor time management are major contributors to rework and material waste in construction projects. For instance, Rehan et al. (2024) found that design errors and Requests

for Information (RFIs) significantly increase project delays and costs, while also contributing to material inefficiencies and waste due to rework and miscommunication. Similarly, Afzal et al. (2024) emphasized that ineffective communication and weak leadership are critical barriers to successful project implementation, often resulting in coordination failures and inefficiencies. These operational shortcomings not only reduce productivity but also hinder the achievement of sustainability goals in the construction sector. As Kabirifar et al. (2020) argue, addressing these challenges through effective waste management and improved project coordination is essential for enhancing both environmental and economic performance.

Construction waste is a well-documented contributor to environmental degradation, with global studies identifying material mismanagement, rework, and inefficiencies during early project phases such as planning and design as key causes (Ajayi & Oyedele, 2018; Osmani et al., 2008). Although advancements in construction technologies and project management practices have been made, these challenges continue to affect project outcomes across various international contexts. This highlights the ongoing need to improve documentation, communication, and coordination processes within the industry.

In contrast, there is limited empirical research that specifically examines these issues within the New Zealand construction sector. The local context remains underexplored, particularly in relation to how paperwork inefficiencies, time management, and design-related rework contribute to construction waste. This study aims to address that gap by investigating the specific factors influencing waste generation in New Zealand. It also explores how targeted improvements in documentation and project coordination can enhance efficiency and support more sustainable construction practices.

LITERATURE REVIEW

Globally, the construction sector generates a substantial amount of waste. In New Zealand, construction and demolition (C&D) waste presents a growing challenge, with approximately 7 million tonnes produced annually. This volume places significant pressure on landfills and contributes to environmental concerns such as greenhouse gas emissions and resource depletion (Equip2 Team, 2024). Approximately half of the waste sent to landfills originates from C&D activities, and each new home constructed generates around four tonnes of waste (BRANZ, 2022). Despite a focus on improving the operational performance of buildings, C&D waste remains a significant issue (OffsiteNZ, 2021). Accounting for 40–50% of total landfill waste (BRANZ, 2024), this highlights the pressing need for more sustainable construction practices. Strategies such as deconstruction, design for deconstruction, and offsite construction are being explored in New Zealand to reduce waste, cut carbon emissions, and conserve resources.

Global Perspectives on Construction Waste Generation

Internationally, construction waste is a persistent issue. In Europe, the construction sector generates around 820 million tonnes of C&D waste annually, accounting for 46% of total waste (Gálvez-Martos et al., 2018). Deconstruction is increasingly seen as a sustainable alternative to demolition Bertino et al. (2021) highlight its role in material recovery and resource efficiency, while Zaman et al. (2018) emphasize its potential for repurposing materials and raising public awareness.

In Australia, urbanisation and economic growth have driven construction activity, resulting in 27 million tonnes of C&D waste in 2019–2020; a 61% increase since 2006–2007 (Department of Agriculture, Water and the Environment, 2020). C&D waste now accounts for over 44% of total waste, with a 47% recycling rate.

The UK's Zero Avoidable Waste (ZAW) strategy aims to eliminate avoidable waste by 2050 (Adams et al., 2020).

Despite a 90% recovery rate, significant landfill use persists (Government, 2022). ZAW implementation requires circular economy principles, design for deconstruction, and life cycle assessments. Key challenges include poor data, inconsistent classifications, and over-specification.

Singapore, a land-scarce nation, has maintained a 99% C&D waste recycling rate since 2013 (NEA, 2024). This success is attributed to coordinated efforts and strict regulatory frameworks, including mandatory demolition plans and risk assessments (BCA, 2011). Singapore's model demonstrates how strong policy and documentation requirements can drive sustainable outcomes.

Construction Waste Regulations and Policies in New Zealand

New Zealand, like other nations, faces significant climate challenges exacerbated by construction-related activities. The Building for Climate Change (BfCC) programme aims for "near- zero- carbon" buildings by 2050 (MBIE, 2020). However, despite this vision, traditional construction practices often resist change. This resistance is compounded by gaps between policy intent and on-site implementation. For example, while regulations promote sustainability, stakeholder practices often lag behind due to economic, cultural, or informational barriers. Bridging this policy-practice gap requires not only regulatory enforcement but also improved documentation, clearer responsibilities, and stronger stakeholder engagement (Doan et al., 2023).

Influence of Construction Practices and Technologies

The planning and design phases of construction projects are pivotal in shaping the trajectory of waste generation across different stages of a project. These early stages involve defining project objectives, allocating resources, and establishing workflows, all of which directly impact efficiency, material usage, and sustainability downstream. The adoption of advanced construction practices and technologies during these phases can significantly mitigate material wastage, enhance efficiency, and promote sustainability. Integrating Building Information Modelling (BIM) is a key strategy for reducing construction waste. BIM enables early clash detection and coordinates design, minimising errors and rework (Eze et al., 2024). Virtual Reality (VR) complements BIM by allowing stakeholders to visualise designs and identify issues before construction, improving communication and decision-making (Wang, 2021). Lean construction further reduces waste by eliminating non-value-adding activities and enhancing workflow. In New Zealand, combining Lean with BIM has shown promise in improving efficiency(Likita et al., 2022). Prefabrication and modular construction also contribute by reducing on-site waste and improving quality control, with higher prefabrication levels linked to lower waste generation (Shahzad & Luo, 2020).

Despite these advances, traditional practices still lead to waste due to poor coordination and resistance to adopting new technologies like VR and Lean-BIM(Likita et al., 2022). Embracing modern methods and fostering stakeholder engagement during planning and design can significantly enhance sustainability and project efficiency.

Stakeholder Contributions to Waste Generation

The design and planning phase of construction projects plays a pivotal role in influencing waste generation across the project lifecycle. Effective coordination among architects, engineers, clients, project managers, and contractors—particularly through early contractor involvement (ECI)—is essential to minimizing inefficiencies and material waste. Architects shape the project's vision, but misalignments with engineering designs due to poor communication can often lead to rework and resource loss (Eze et al., 2024). Clients also contribute to waste through late-stage changes in scope or preferences, which trigger redesigns and delays (Jalaei, 2019). Project managers serve as key

facilitators, and when communication breaks down or oversight is lacking, conflicting priorities can emerge, further exacerbating inefficiencies(Likita et al., 2022).

Contractors engaged early in the process offer valuable insights into constructability and cost-effective solutions, helping to prevent impractical designs and overlooked constraints (Shahzad & Luo, 2020). However, when their input is underutilized, opportunities for waste reduction are missed. To address these challenges, fostering collaboration among stakeholders is vital. Tools like Building Information Modelling (BIM) enhance coordination by enabling early conflict resolution and shared visualization(Eze et al., 2024). Lean principles also support waste-minimisation through streamlined processes and continuous improvement.

Although tools and frameworks exist, their effectiveness depends on stakeholder willingness to collaborate and share information. This reinforces the earlier point that policy alone is insufficient. Practical implementation requires cultural and procedural shifts within the industry. Linking this back to New Zealand's regulatory context, the success of waste reduction strategies depends not only on policy design but also on how well stakeholders align their practices with these goals through proactive engagement and integrated workflows.

Economic and Environmental Implications of Construction Waste

The construction sector is a major contributor to global resource consumption, accounting for 39% of energy-related CO_2 emissions (UN, 2021) and 35% of landfill waste (OECD, 2020). Waste on-site leads to additional costs for replacement, rework, transport, and disposal, negatively impacting project economics. Studies have assessed the environmental impact of construction waste using methods like Life Cycle Assessment (LCA) (Ortiz et al., 2009) and various waste management strategies including selective demolition and deconstruction (Coelho & de Brito, 2012, 2013; Lu et al., 2011). Significant waste also arises from design and planning inefficiencies, such as poor coordination and over-specification, which lead to rework, delays, and excess material use (Akinade et al., 2017; Hossain et al., 2020; Sassanelli et al., 2019). These issues contradict Lean construction principles, which aim to minimize waste and maximise value.

Environmental consequences of poor planning include resource depletion, pollution, and carbon emissions due to overuse of materials, extended equipment use, and increased transportation (Stanitsas et al., 2021; Martins et al., 2019). Improper disposal and rework can also contaminate soil and water, affecting ecosystems and human health. Sustainable design choices and maintenance practices significantly influence a building's recyclability and reusability at end-of-life (Jalaei, Zoghi & Khoshand, 2021). Addressing inefficiencies through Lean methodologies, early collaboration, and iterative design can reduce both economic and environmental impacts.

Barriers to Waste Minimization in Construction

Numerous barriers towards waste minimization have been identified in the literature (Boser et al., 2010; WALGA, 2013). These studies identified significant barriers to recycling and reuse of construction and demolition (C&D) waste in the Australian Capital Region, mirroring global findings. Key obstacles include limited knowledge about recycling opportunities, contamination of recyclables due to improper separation or space constraints, and a lack of markets for recycled materials. Technological challenges, higher costs of recycling processes compared to virgin material production, and the absence of design for deconstruction further hinder recycling efforts. Economic disincentives, such as low landfill gate prices, inadequate government policy support, and a lack of industry confidence in recycled materials, exacerbate the issue. Additionally, poor communication within the industry and insufficient infrastructure contribute to the problem. Low-value and low-volume materials are often landfilled because stockpiling for recycling

is uneconomical. While the study highlights these barriers, its findings may not be universally applicable beyond the Australian Capital Region. Of the 20 proposed strategies, many emphasize the need for stronger government policies and improved information sharing, alongside the necessity for enhanced education and further research to shift industry perceptions. Olanrewaju and Ogunmakinde (2020) identified the primary barriers to construction waste minimization as a lack of training, poorly defined responsibilities, lack of interest from clients and the widespread acceptance of waste as inevitable. Their research employed a survey of architects with at least three years of experience, analyzing the data using the Relative Importance Index (RII). The study concludes that architects play a pivotal role in minimising construction waste and emphasizes the importance of enhancing training programs and educating clients to reduce waste in the construction process further. Ding et al. (2018) identified several key barriers to construction waste reduction during the design phase. First, improper design was noted as a major contributor to construction rework and material waste. Despite the recognized importance of waste minimization through design, its implementation remains limited. Frequent design modifications further increase waste generation. Additionally, the attitudes of designers and the constraints they encounter often impede the adoption of effective waste-minimization practices. Historically, the lack of focus on waste reduction during the design stage has been prevalent, with more attention given to waste management during construction. These barriers underscore the need for more integrated, proactive approaches to waste reduction that begin at the design phase.

Summary

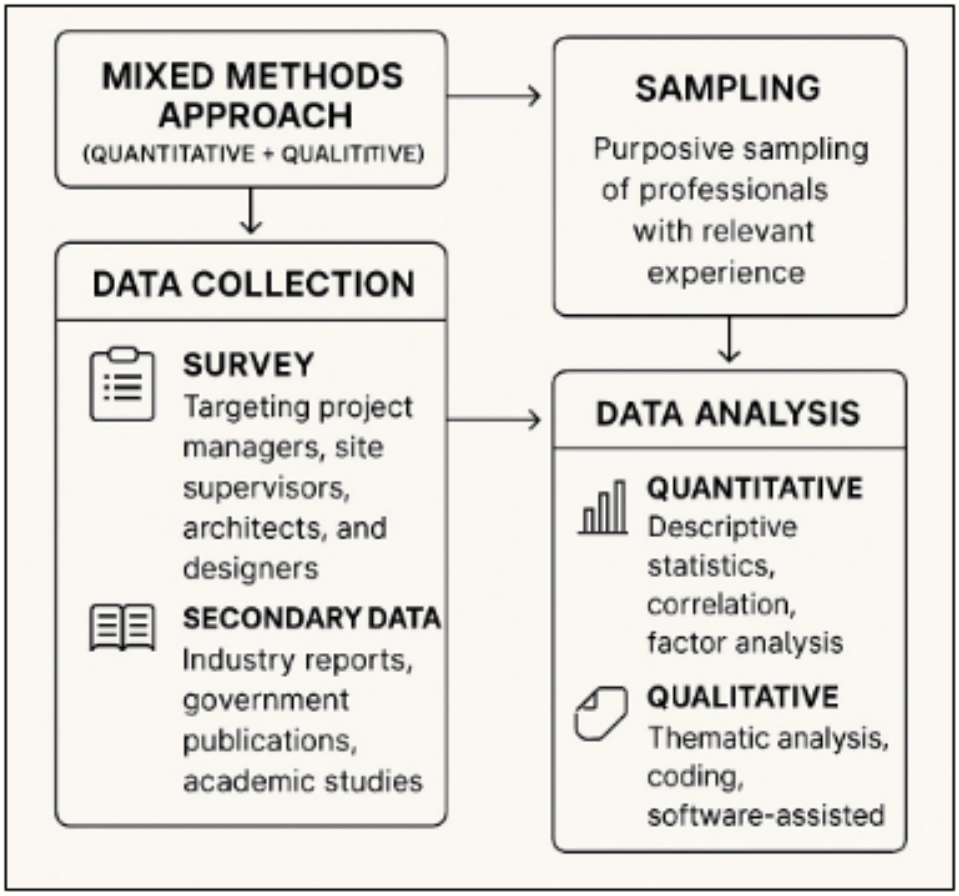
The reviewed literature highlights a consistent global concern regarding construction and demolition waste, with significant contributions to environmental degradation and project inefficiencies. While international studies have explored the roles of documentation, planning, stakeholder coordination, and technological interventions in waste reduction, there remains a notable gap in localized research specific to New Zealand. The integration of Lean and BIM practices, though promising, is still limited in the local context. Furthermore, policy frameworks such as the Building for Climate Change programme signal intent, but practical implementation is hindered by stakeholder misalignment and systemic barriers. This review underscores the interconnected nature of poor documentation, time delays, rework, and waste, all of which contribute to broader inefficiencies. Addressing these challenges requires a more integrated approach that aligns policy, practice, and stakeholder engagement to support sustainable construction outcomes in New Zealand.

METHODOLOGY

This study adopted a mixed methods approach to provide a balanced understanding of the factors contributing to construction waste. The quantitative component captured prevalent inefficiencies, while the qualitative aspect explored deeper, context-specific insights from professionals in the field. Data for the quantitative component were collected through a structured online survey administered via Google Forms, comprising both closed and open-ended questions. The survey targeted professionals involved in the planning and design stages of construction projects in New Zealand, including project managers, designers, engineers, architects, contractors, and quantity surveyors. Participants were recruited using a convenience sampling method, primarily through professional networks and social media platforms such as LinkedIn. Interested individuals received a formal invitation via email, which included a Participant Information Sheet, a consent statement, and a link to the questionnaire. To broaden the participant pool, a snowball sampling approach was also employed, whereby participants were encouraged to share the survey with other eligible professionals. Inclusion criteria required participants to be 18 years or older and have relevant construc-

tion experience. Participation was voluntary and anonymous, and respondents could withdraw at any time before submitting their responses. For the qualitative component, open-ended survey responses were analysed using reflexive thematic analysis, which acknowledges the active role of the researcher in interpreting and developing themes (Braun & Clarke, 2006). The six-phase process outlined by Braun and Clarke was followed: (1) familiarization with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. Survey responses were analysed using descriptive statistics to highlight the most frequently cited inefficiencies. Correlation analysis was conducted to examine relationships, such as those between poor time management and rework incidents. Where appropriate, factor analysis was used to uncover underlying patterns within the data. For the qualitative component, thematic analysis was applied to identify recurring themes in the interview data. Responses were coded and categorized into key themes, such as communication gaps and specific design inefficiencies. Qualitative analysis software supported the coding process and enhanced analytical rigor. Figure 1 presents the flowchart of the methodology used in this research.

Figure 1: Methodology overview adopted in this research.

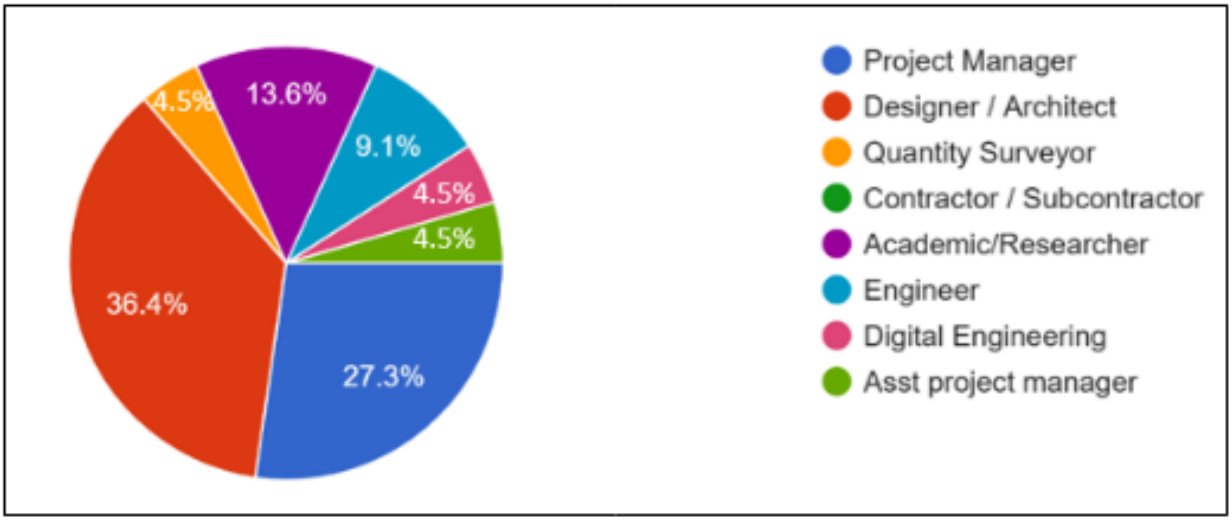


DATA SUMMARY

The survey gathered responses from 30 professionals in the construction industry, representing a diverse mix of roles. As shown in Figure 2, Designers and architects made up the largest group at 36%, followed by project managers at 27%, who highlighted coordination and scheduling issues. Academics and researchers accounted for 14%, offering

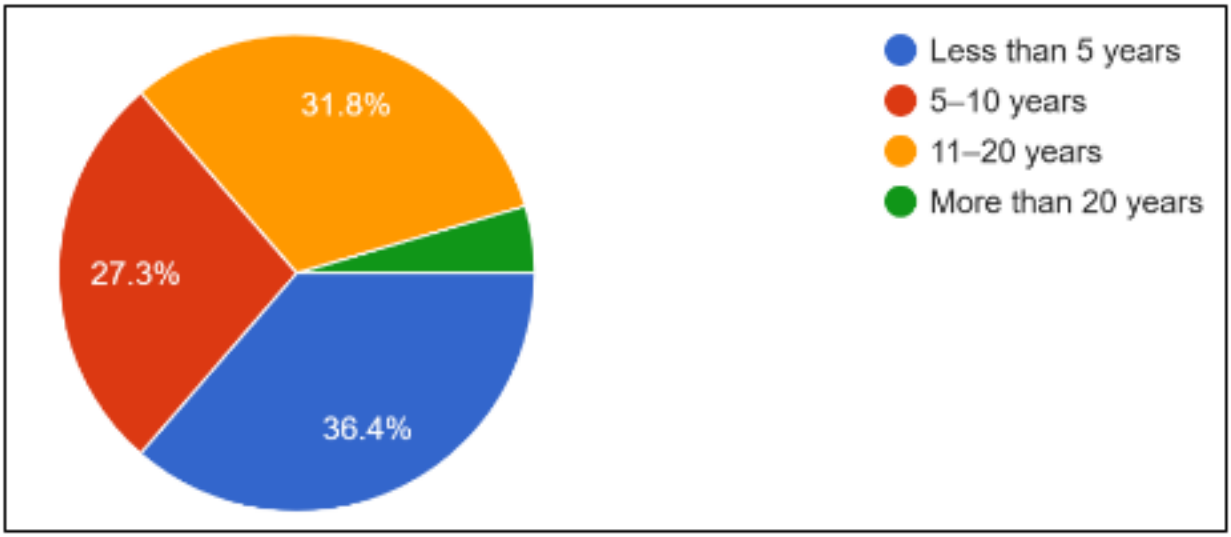
broader industry perspectives. Engineers represented 9%, focusing on technical impacts of unclear documentation. The remaining 14% included quantity surveyors, assistant project managers, and digital engineering specialists, providing additional insights on cost, planning, and digital practices. This diversity supports a balanced view of how poor documentation and time management contribute to construction waste and inefficiency.

Figure 2: Role distribution of survey respondents in the construction industry.



In terms of industry experience, 36% of respondents had less than 5 years of experience, 27% had between 5 and 10 years, 32% had between 11 and 20 years, and 5% had more than 20 years as shown in Figure 3. This indicates a strong representation from early and mid-career professionals, with limited input from highly experienced individuals.

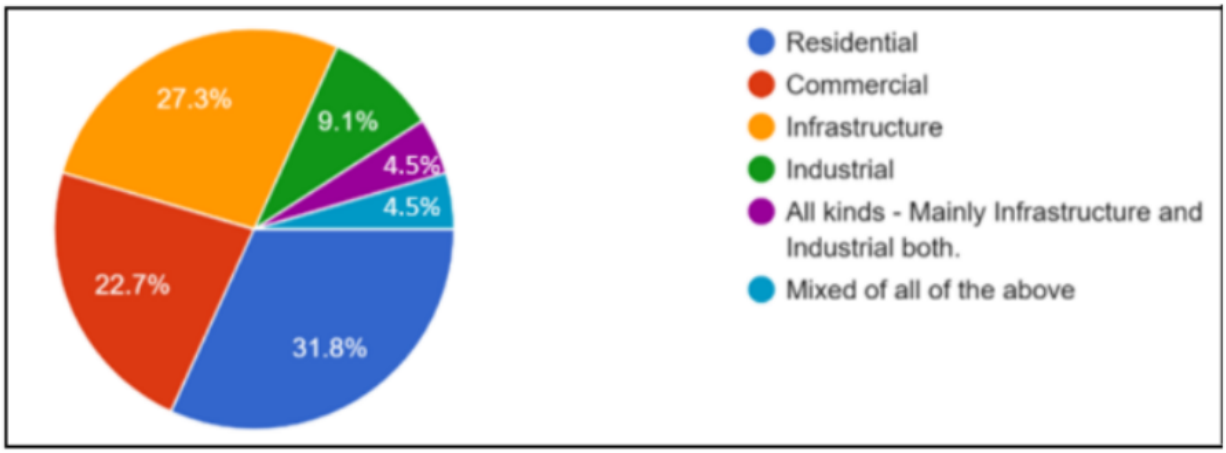
Figure 3: Years of industry experience among survey respondents.



Regarding project types, 32% of respondents primarily work on residential projects, 27% on infrastructure, and 23%

on commercial developments. The remaining 18% indicated involvement in other types, including industrial, mixed-use, or a variety of project types. This mix reflects a broad exposure to different construction contexts relevant to documentation and time management practices. Figure 4 illustrates the distribution of the type of work of the respondents.

Figure 4: Primary project types worked on by respondents.



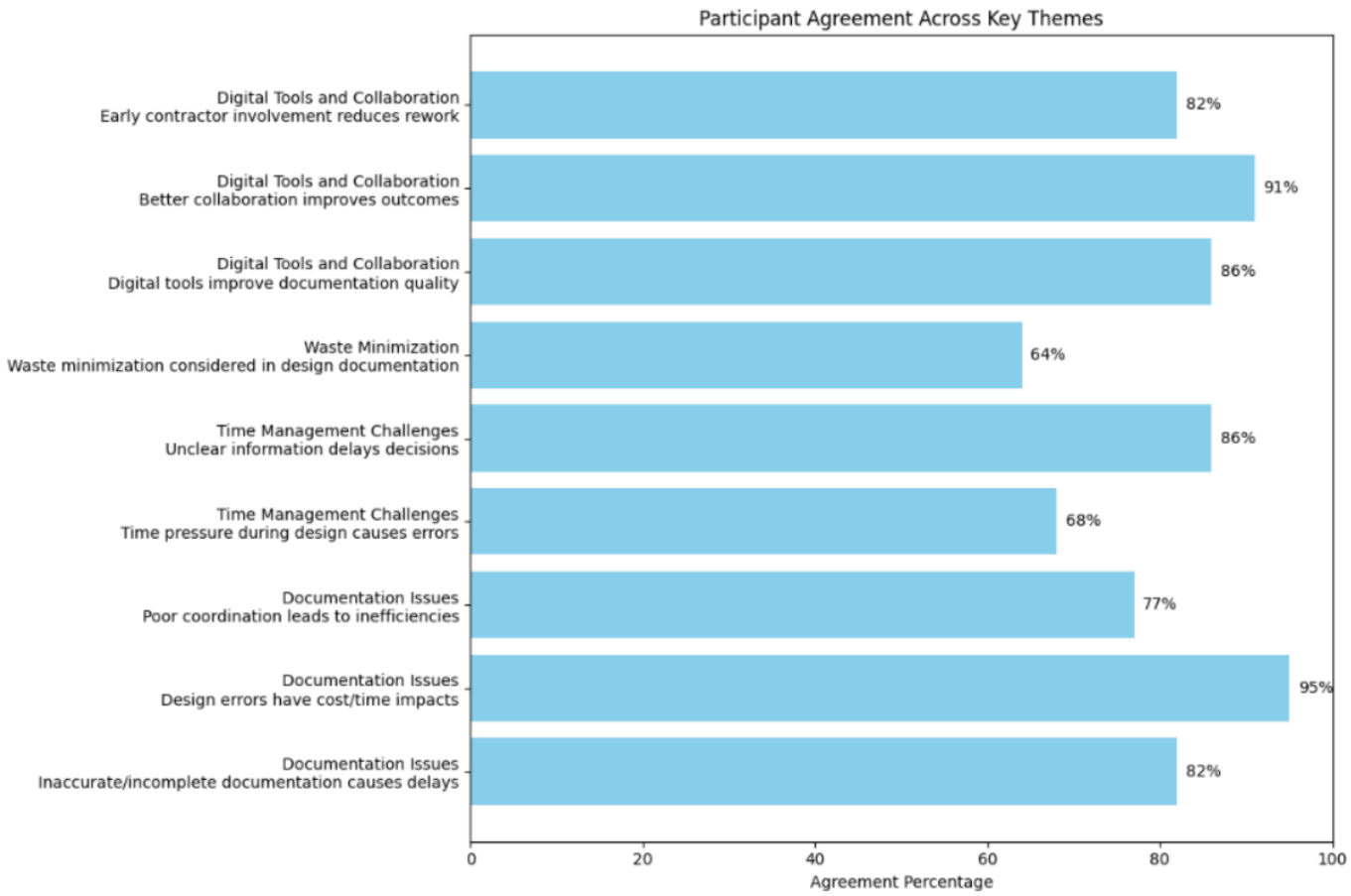
Key Findings from Likert Scale Responses

Participants were asked to rate their agreement with statements related to documentation, time management, waste, and collaboration. The responses highlight several areas of strong consensus:

- **Documentation Issues**. A large majority (82%) agreed that inaccurate or incomplete documentation causes delays, while 95% felt that design errors have clear cost and time impacts. Additionally, 77% agreed that poor coordination between design and construction teams leads to inefficiencies.
- **Time Management Challenges.** About 68% agreed that time pressure during the design phase results in errors, and 86% believed that unclear information delays decision-making.
- **Waste Minimization.** Responses were more varied, with only 64% agreeing that waste minimization is considered in design documentation, suggesting room for improvement in this area.
- **Digital Tools and Collaboration**. Most participants supported the use of digital solutions, with 86% agreeing that digital tools improve documentation quality. A strong 91% agreed that better collaboration between designers and builders leads to improved project outcomes. Additionally, 82% supported early contractor involvement to help reduce rework. Figure 5 summarises the findings of this analysis.

These findings reflect a shared industry view that improving documentation quality, communication, and collaboration can significantly reduce inefficiencies and waste.

Figure 5: Participant agreement percentages across key themes in design and construction practices



Additional Insights from Communication and Collaboration Metrics

Communication challenges during the planning and design phases were frequently reported, with 55% of respondents indicating such issues occur ”sometimes” and 45% stating they happen ”often” or ”very often.” These results reinforce earlier findings that unclear communication is a major contributor to inefficiencies and rework. Documentation issues were also prominent, with missing details (36%) and contradictions between disciplines (27%) being the most cited problems. Additional concerns included version control, ambiguous language, outdated specifications, and conflicting information, highlighting the need for improved document management and interdisciplinary coordination. Figure 6 summarises the frequency of communication issues during the planning and design phase.

Respondents expressed strong support for digital tools, with 86% agreeing or strongly agreeing that such technologies have improved documentation quality. Similarly, 91% endorsed improved scheduling techniques to reduced planning-related delays. Early contractor involvement (ECI) was supported by 82% of participants, and 91% favoured better collaboration between designers and builders. These findings emphasize the importance of integrated project teams, early stakeholder engagement, and the adoption of digital and planning tools to enhance project outcomes and reduce rework. Figure 7 summarises the distribution of the most common documentation issues by the respondents.

Figure 6: Frequency of communication issues during the planning and design phase

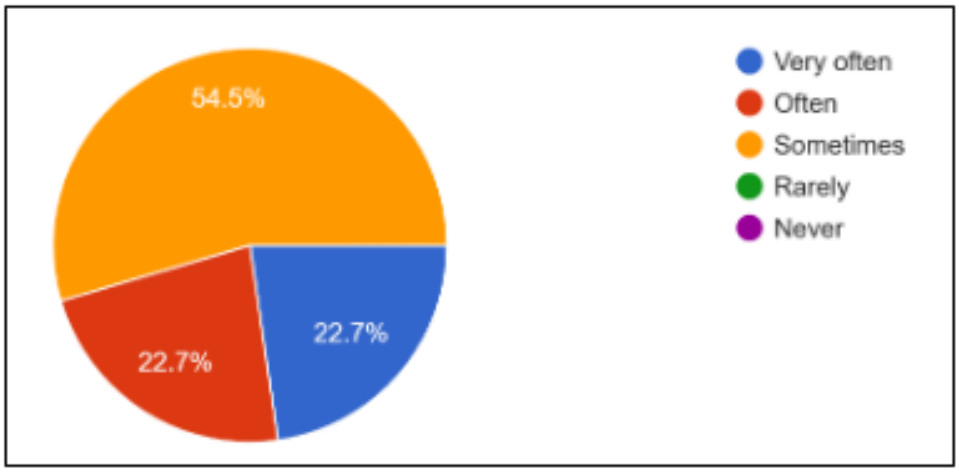
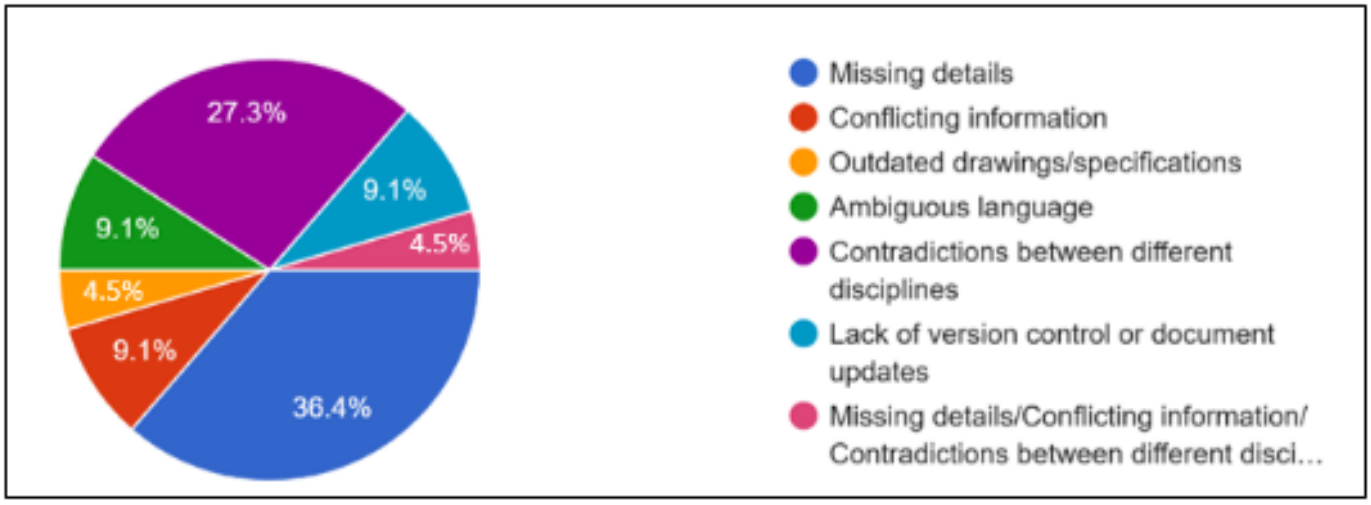


Figure 7: Distribution of the most common documentation issues reported by respondents.



Thematic Analysis of Open-Ended Responses

Participants provided detailed qualitative feedback highlighting key challenges and potential improvements in construction documentation and time management. A thematic analysis, supported by word frequency counts, revealed several recurring patterns:

1. Documentation Issues

Many respondents cited missing or unclear details, ambiguous language, and outdated or contradictory drawings across disciplines. Lack of version control and inconsistencies between architectural, structural, and services documentation were frequently mentioned as sources of confusion and rework.

2. Causes of Rework

Frequent design changes during construction and poor coordination were dominant themes. Several participants highlighted client-driven changes and early-phase planning issues, particularly the lack of clarity in initial project stages.

3. Suggestions for Improvement

Common suggestions included early contractor involvement (ECI), improved cross-disciplinary collaboration, and wider adoption of digital tools such as BIM for clash detection and visual coordination. Others emphasized sustainable design practices like modular construction and deconstruction planning, alongside training and stronger stakeholder engagement.

DISCUSSION

The findings from both the Likert scale responses and thematic analysis reveal consistent challenges in documentation, time management, and collaboration within construction projects. These issues are not isolated but interconnected, contributing to inefficiencies, rework, and waste. The high level of agreement among participants regarding the impact of poor documentation highlights its role as a systemic issue. Inaccurate, incomplete, or contradictory documents not only delay decision-making but also lead to costly rework. This reinforces existing literature on fragmented design processes and suggests a pressing need for integrated documentation systems and standardised practices across disciplines. Time management challenges, particularly during the design phase, were strongly linked to errors and delays. This suggests that current project timelines may undervalue the importance of thorough planning and coordination. The findings support calls for more realistic scheduling and better front-end planning to reduce downstream inefficiencies. While sustainability was acknowledged, the relatively lower agreement on its consideration in design documentation indicates that it remains a secondary priority. This gap between sustainability goals and actual design practices points to the need for stronger frameworks and incentives to embed waste minimisation into early project stages.

Participants overwhelmingly supported digital tools and collaborative practices such as early contractor involvement (ECI). These are seen as key enablers of improved documentation and reduced rework. However, their practical implementation may be hindered by procurement models, training gaps, and resistance to change. This suggests that while the industry is conceptually aligned with integrated project delivery (IPD), operational barriers remain. Frequent communication issues, especially during planning and design, were identified as major contributors to inefficiencies. The qualitative data revealed problems such as ambiguous language, outdated specifications, and conflicting information. These findings highlight the importance of not just technical coordination but also clear communication protocols and interdisciplinary collaboration.

CONCLUSIONS AND RECOMMENDATIONS

This study examined how poor documentation and time management contribute to construction waste and inefficiencies. Drawing on responses from 30 professionals across diverse roles and experience levels, several key conclusions can be made:

- Documentation deficiencies including missing details, contradictory information, and lack of version control are widespread and significantly contribute to delays and rework.
- Time management challenges, especially during design and planning, often arise from unclear communication and delayed decision-making due to insufficient or ambiguous information.
- Rework is frequently driven by design changes, poor interdisciplinary coordination, and misaligned stakeholder expectations.
- Digital tools such as BIM and project management software are widely recognised for improving documentation quality and reducing errors.
- Early contractor involvement (ECI) and collaborative planning between designers and builders are strongly supported as strategies to enhance project outcomes and minimise waste.
- Improved scheduling techniques are seen as effective in mitigating planning-related delays.

These findings reinforce the need for integrated project delivery, robust documentation practices, and proactive communication strategies to reduce inefficiencies and construction waste.

Recommendations include:

- Encouraging early stakeholder engagement and cross-disciplinary collaboration from the design phase.
- Investing in digital tools and training to support better documentation and coordination.
- Revisiting procurement and scheduling models to allow sufficient time for planning and review.
- Embedding sustainability and waste minimisation into design documentation standards.

Future research could explore the real-world effectiveness of specific digital tools and collaborative frameworks, particularly in complex or large-scale projects.

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Conceptual

Improving Cyber-Security Education and Awareness Programs for Small Teams in Enterprises

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ABSTRACT

In the contemporary digital landscape, small teams within enterprises are often targeted by cyber-criminals who seek to breach their security and access sensitive information. This article examines a range of strategies and resources to support cyber-security education and awareness programs that are tailored to the needs of small teams within enterprises. The aim is to empower individuals and teams to recognize and respond effectively to cyber-threats. After briefly explaining what cyber-security is and the type of threats a team may encounter, the article explores education strategies discussed in the current literature. The authors then present examples of resources they have identified or developed during this research. This includes an analysis of an ISO standard that presents an example risk-assessment plan as well as an interview sheet we developed for performing an initial assessment of a teams cyber-security awareness level. Strategies for educating teams about how to address typical cyber-security situations a team may encounter, such as email phishing scams, are then explored in the context of an example training plan that can be used to facilitate interactive and engaging learning. The article concludes that teams often face unique challenges, including limited resources, varying levels of technical expertise, and the ever-present risk of underestimating cyber-threats. Promoting a proactive cyber-security culture within a small team by using resources organised into an systematic program is a crucial step in building a resilient and security-aware workforce.

Keywords: Cyber-Security Awareness, Education, Team Development, Resources, and Small-to-Medium Enterprises.

INTRODUCTION

Technology has long been a key driver and enabler of modern business practice. Besides offering advantages, online technologies now present many new challenges: one is the risk of cyber-attack. A cyber-attack is an intentional effort by an outside entity to expose or steal information and often to disable or destroy an organisation's digital infrastructure (IBM, 2021). A typical example is a Ransomware exploit, a cyber-attack that encrypts computer files and sometimes locks the computer, rendering it completely unusable until a ransom payment is made (Park et al., 2022). In an era where the risk of on-line threats like this are always present, the necessity for robust cyber-security measures has never been more critical.

While the focus of cyber-security education has traditionally been on large corporations, smaller groups within Small to Medium Enterprises (SMEs) often face unique challenges. Alahmari and Duncan (2020) explain that SMEs typically employ 250 or less staff. In the United Kingdom (UK) in 2020, there were over 5.6 million SMEs, employing over 16 million staff. These organisations make a significant contribution to a national economy: in 2018, UK SMEs had a turnover in excess of £1,994 billion.

Being Secure

In the past, companies understood that "Being Secure" meant keeping accounting records, intellectual property, and client information safe behind locked doors within their business premises. There, it could only be accessed by their staff. The first Time-Sharing computer systems that allowed users to manage and exchange information remotely were not available until 1964 (Kemeny & Kurtz, 1968). Hildebrandt et al. (1980) discuss the later emergence of the first fully self-contained in-house computer systems that became available in the 1970s. These allowed organisations to store and manage data on their own computers within their own premises. This on-going digitisation of information required organisations to consider how to prevent criminals accessing their valuable intellectual property while inside their buildings (Härting et al., 2022). After that, the introduction of Remote Networking, the Personal Computer, and the Internet meant that information technology became more affordable and available to a wider segment of society, including criminals (Aieshwaryaa, 2022; Smith et al., 2004). This meant that the threat of cyber-crime, executed remotely to breach their security and steal valuable information, was a reality that could no longer be ignored.

Building a cyber-secure company environment

Riggs et al. (2023) explain that building a company environment that is cyber-secure is a complex task, typically involving two distinct aspects.

The first aspect involves the electronic infrastructure needed to protect the computers. This is accomplished by configuring intrusion-control software and hardware devices such as electronic firewalls (Blansit, 2009). Figure 1 shows a Netgate SG-1100 firewall that is commonly used to protect SMEs (Netgate, 2025). Firewalls are electronic gateways that implement rules to enable authorised users to access the information being stored in the companies computers while restricting access by outside unauthorised systems connected to the internet. While it is important for all staff to have a basic understanding of the purpose and need for such equipment, they do not have to be able to configure such devices themselves. For smaller organisations, that is often a task contracted to specialised outside cyber-security consultants.

Figure 1: A typical Netgate SME firewall appliance

The second aspect discussed by Reggs et al. is more important to the majority of employees. How they act responsibly, day-by-day, not falling prey to cyber-attacks through their actions, is a behavior that has to become both a personal habit and part of their organisational culture. Hence, implementing cyber-security education for these users aims to build awareness, foster good practices, and empower employees to recognize and respond to potential threats when they encounter them (Al-Daeef et al., 2017).

Hence choosing or creating a cost-effective program that is appropriate for small, resource-challenged teams is not simple. Many larger companies outsource their cyber-security training programs to specialist organisations. However, that may not be financially viable for all SMEs (Annarelli et al., 2021). By emphasizing ongoing education, practical engagement, and regular updates to the curriculum, organizations can cultivate a culture of cyber-security awareness and resilience.

The rest of the article focuses on recommendations from the current literature on how to address the challenges

faced by small teams. It then proposes simple guidelines for best practices, as outlined in the literature, to facilitate cyber-security education and awareness (Romansky & Noninska, 2020). It considers examples of training material that utilize interactive and practical exercises. The goal is to create an engaging, sustainable, and cost-effective learning environment (Chidukwani et al., 2022). Teams must also learn how to adapt to changes in the cyber-security threat landscape by participating in on-going education (Hatzivasilis et al., 2020).

LITERATURE REVIEW

In their 2018 State of Cyber Security in SMEs study, Bada and Nurse (2019) identified three main challenges faced by small organisations:

- Not having the in-house expertise needed to mitigate cyber-risk.
- Information Technology (IT) budget constraints.
- A general lack of understanding about how to protect against cyber-attacks.

The authors emphasise that enhancing awareness of cyber-threats should be a critical part of training programs, since it will encourage organisations to find ways to address these three issues. Making sure that employees understand company cyber-security guidelines should be a key part of both the on-boarding of new staff and the regular up-skilling of all team members. Hight (2005, page 2) comments that "As a human is generally considered the weakest link in a computer system, professional training is now becoming a necessity". This implies that companies also need to determine when it is appropriate to bring in outside resources to augment their own training initiatives.

Al-Daeef et al. (2017) explain that well-designed user training methods can effectively enhance awareness and security behaviors. The authors describe a typical criminal tactic called Phishing (NIST, 2025), a type of social engineering where cyber-criminals try to deceive users into sharing sensitive information. This can happen when they inadvertently or deliberately follow links on external web sites, in emails, or other documents they receive. This exploit can connect their computers to malicious external web sites. Once connected, the software on these sites can inject viruses or other "trojan" software entities into the user's computer system. This creates a gateway via that computer into the rest of the companies network. When cyber-criminals gain access in this way, they can explore and mine information undetected by staff, sometimes for extended periods of time. Akhgar et al. (2014) present examples of such long-term intrusions and the consequences of this sort of criminal activity.

Techniques for enhancing cyber-security awareness

Mistakes made by individuals related to their use of technologies are not always solved just by adding more technology (Orlikowski & Gash, 1994). Education is usually more effective when delivered by appropriate awareness training programs since there are limitations to how well technology can alleviate the consequences of user's mistakes. Gundu (2019) found that SMEs need to understand more about possible vulnerabilities rather than understanding how to implement security tools. This encourages them to better perform relevant self-assessment of the risks to their particular situation.

Hight (2005) proposes a range of strategies. First, training sessions need to be conducted frequently using company-approved material that includes information about the latest cyber-threats, how to recognize them, and how to adopt best practice using representative examples from historical cases. These sessions can be interactive with quizzes, games, and real-life scenario simulations.

Moreover, organizations should send simulated phishing emails to test employee's vigilance and response. This activity helps reinforce learning and provides practical experience in identifying suspicious communications. Secondly, establish and promote clear communication channels where associates can ask questions about potential threats, best practice, and report suspicious activities without fear of reprisal. Thirdly, use a variety of engaging content such as short videos, infographics, campaign events, and interactive modules to make learning about cyber-security more interesting and less tedious. Finally, organizations are recommended to provide continuous updates on new and emerging threats. This could include the use of newsletters, intranet posts, or brief informational videos to keep everyone informed (Bada & Nurse, 2019).

Bada and Nurse (2019, page 4) further explain that "It is well recognized that an individual's knowledge skills and understanding of cyber-security, as well as their experiences, perceptions, attitudes, and beliefs, are the main influences on their behavior". The authors explain that there is a set of key issues that users should focus on. These include teaching people how to identify phishing emails and malicious links by using real-world examples. Practitioners also need to provide instructions to help users learn how to respond appropriately when a security incident occurs. Other aspects such as secure passwords practices, safe browsing, correct data handling outside the organisation, and the appropriate use of mobile devices are initiatives which promote the user's goal to gain knowledge and behave well (Santa, 2010).

Organizations should be encouraged to create an environment where security is a shared responsibility while fostering a culture of security awareness. Those key strategies could be implemented to include ensuring that leadership priorities and active participation in cyber-security initiatives remain a key focus. This sets a tone of seriousness and commitment throughout the organization.

Key considerations for developing an effective cyber-security training program

The examples discussed in this section emphasised that promoting and maintaining excellent personal cyber-security behavior is the most important goal for any cyber-security education program. Daswani and Elbayadi (2021) highlight three issues that need to be considered when creating cyber-security training activities:

- The cyber-security threat landscape is changing daily. At the same time, a company's infrastructure is probably being enhanced with new equipment and software upgrades. New mobile devices, including small Internet Of Things (IoT) electronic devices (Gazis, 2021), which include security monitoring and building access control equipment, are also software devices which are attack targets for cyber-criminals.

- The number of outside connections and the volume of data moving in and out of an organisation is likely to be changing regularly. New Cloud services, including on-line accounting, travel-booking, and payroll systems are often changed as a company's needs evolve.

- Malware introduced into software during normal upgrades, including malicious macros in applications, is a serious issue. The company's cyber-security management plan should require regular updates to anti-virus software on all computers and ensuring that subscriptions remain up-to-date.

This section has emphasised that developing a cyber-security education program for an organisation is not a one-time task. Once established, it must be re-evaluated at regular intervals as both the technology platforms and the profile of staff employed evolves as the SME grows.

GUIDELINES FOR CREATING AND IMPLEMENTING A SME CYBER-SECURITY EDUCATION PROGRAM

It is important to develop, trial, and then enhance custom content for individual SME teams, since no two organisations will present the same opportunities, called a "Threat-Attack Surfaces", to cyber-criminals (Matkowsky, 2023). This implies that there is a need to understand and review potential cyber-threats and vulnerabilities that the team is most likely to encounter in their daily activities. This section summarises a range of strategies from the literature presented in the previous section as well as identifying other resources that are available from the internet. Teams can use these ideas to stimulate their thinking and then to craft their own cyber-security education programs.

Planning and up-skilling of the cyber-security lead team

A group of company staff can be co-opted to form a Cyber-Security Management Implementation team. They should have a range of skills, but do not necessarily need to be highly-technical computer experts. They are primarily representative of the typical company staff members. Working through example Cyber-Security plans and policy documents available from on-line sources will help them to formulate questions and define topics they need to investigate further. Security awareness programs should primarily be designed to influence users' behavior and understanding levels, giving them confidence to manage their particular situation (Wilson, Hash, et al., 2003).

One of the most fundamental, well-established, and internationally-recognised set of guidelines is the *Framework for Improving Critical Infrastructure Cybersecurity* (NIST, 2018) published by the National Institute of Standards and Technology (NIST). The document explains that its role is to provide a set of industry standards for best-practice cyber-security programs that are applicable to private sector needs and are both "voluntary" and "risk-based" (page 1).

The NIST guidelines stress that any framework an organisation implements must be both flexible and incorporate practices that are "repeatable". By this, they mean that a chosen response to a threat works reliably and is applicable in other circumstances whenever a similar threat is encountered. A proposed plan should provide a framework to achieve aims that NIST recommends (NIST, 2018, page 6):

- Describe the current cyber-security "posture" or state of the organisation.
- Define what the target state is that the organisation wants to achieve and establish. This implies that the team should have well-defined aims for how cyber-secure they want to be. It is understood that no organisation will ever be 100% safe from attack however there should be a well-defined understanding of what "secure-enough" means for their organisation.
- That there are mechanisms in place to identify and prioritise opportunities for improvement.
- That it will be possible to assess progress towards the goals that are being established.
- That teams should be able to communicate to internal and external stakeholders the team's understanding of cyber-security risks.

In summary, any framework or program should facilitate five key activities: identifying threats, protecting infrastructure and data, detecting intrusions, practices for responding, and processes for recovering.

Initial team surveys

Once the initial concepts have been understood by the people tasked with designing the program, one starting point for engaging with other staff is a brief survey that can be used in individual interviews. This can help to gauge employees' existing knowledge and identify potential gaps. Figure 2 is an example of an interview form the authors developed for use in future surveys and case studies, based on recommendations found in the literature review.

Figure 2: Example Survey form for use during one-on-one or department interviews.

Cyber-Security in our Organisation

Department name: _____ Name: _____

Date of interview: _____

No.	Question	Comment	Compliance
1.	What do you know about Cyber-Security?		
2.	Is Cyber-Security important when you handle business information?		
3.	Do you know who to contact if you have questions about our Cyber-Security practices and policies?		
4.	Have you read our Cyber-Security Policies and Guidelines?		
5.	What sort of information do we need to protect?		
6.	Do you know how to protect the data you work it?		
7.	Do you know who to report a Cyber-Security incident or concern to?		
8.	Have you ever downloaded or installed software on your work computer?		
9.	Should you upload business information to on-line platforms such as YouTube, Facebook, or Instagram?		
10.	Do you have any suggestions or comments about how we could become more secure here?		

The form is designed to guide a one-on-one or small team discussion without appearing to be a test. Instead, it is intended to help the team assess their overall level of knowledge by aggregating the results elicited from all participants. The first two questions are general and are designed to establish an environment where questions can be asked freely. The next three questions gauge how well supported and informed staff feel about the information, resources, and training provided to them currently. Question 5 asks if they know what are the most critical resources that they need to protect. Once these concepts have been socialised, practical examples and concerns are elicited in the remaining questions.

Understanding the types of potential cyber-threats

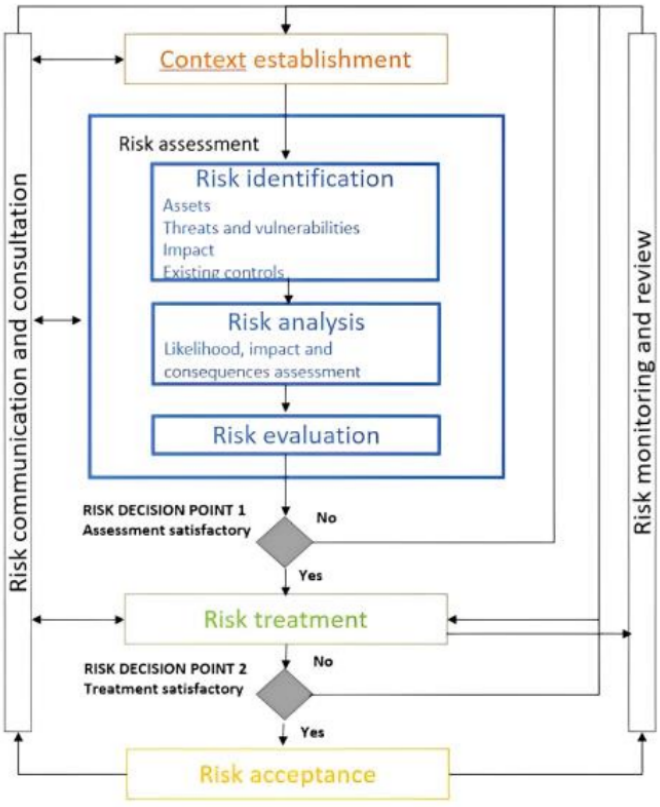
Studying examples of current cyber-threats trains the team to learn how to identify vulnerabilities in their own behavior and systems. A typical example of a serious cyber-threat that the team should understand is a *Ransomware Attack* (Park et al., 2022). The name embodies two important aspects of the threat: the purpose of the attack is to extort a payment from an organisation by holding their data and computers "to ransom" and it is executed by software called "Ransom Malware" (Kramer & Bradfield, 2010). The attackers use this type of software to encrypt important files in the target computers and then lock-down the computers, rendering them completely inaccessible and unusable. The cyber-criminals then promise to decrypt the data and release their hold on the computers in exchange for a ransom payment. Unless the situation is resolved, the information loss is either temporary or in some cases, permanent. The attack causes disruption to the companies operations and financial losses due to work not being completed or the inability to bill customers. NIST(NIST, 2018) provides an example plan that includes guidelines for protecting companies from ransomware attacks. Like many other public resources, it is freely downloadable from the NIST site (Souppaya et al., 2025).

Conducting a risk assessment

Teams should follow international guidelines when conducting a risk assessment of their organisation. The ISO/IEC Standard 27005 (ISO, 2022) outlines a detailed model recommended by Sánchez-García et al. (2023). Figure 3 was extracted from the standard, which outlines the assessment steps that begin with an initial identification of the context in which the risk could occur. An example of a risk context is the way the company staff interact via the internet with their clients, suppliers, and other parties. Is information received in electronic files, uploaded to the companies computers, and then accessed? Part of the assessment includes understanding what malicious content could be carried in those files (Melaku, 2023)

The next steps after a risk context is identified is to find specific situations or environments within the organisation where that risk could cause damage. The team should consider assets, vulnerabilities, and what

Figure 3: ISO/IEC 27005 Risk Assessment Model



the impact of a successful cyber-attack could be. The next step involves a deeper analysis of each aspect uncovered, leading to an evaluation of the risk that can be documented as something to address.

Note that the process is cyclic: not all aspects will necessarily be understood in the first pass. Sánchez-García et al. (2023) caution that it is important to plan sub-steps of risk assessment and identify real metrics for accurate risk assessment calculations. For example, what would it cost to recover or replace a damaged asset? The end result of this analysis should be a set of recommendations for how the risk should be mitigated.

During risk assessment, the SME should ask when or if the risk is such that they should seek outside expert help to mitigate it. Building some parts of an effective management program may require specialised outside technical advice. This can be a worthwhile investment to ensure that the technical aspects of the potential threats can be identified and explained to people in ways they can understand Annarelli et al. (2021) and Landoll (2021).

Employing team building activities and resources

To ensure that training is effective, other interactive and engaging learning methods can be employed. Two examples are sending custom emails that test each user's ability to recognise a phishing attempt (NIST, 2025) and the use of targeted posters and shared self-learning resources.

Posters and other media are also reported to be an effective way of socialising cyber-security practices. Figure 4 shows two typical examples. The poster on the left from Westchester University encourages vigilance by students and staff against phishing attacks, where an intruder tries to gain access to a system by deceiving a user into clicking

Figure 4: Examples of Cyber-Security Awareness Posters that can be displayed in organisations.

on content that can compromise their system (WCUPA, 2024). The second poster from the Australian consultants Caniphish is one of a set of free Cyber-Security Awareness posters they make available to organisations (Caniphish, 2025).

Activities can also include conducting random simulated phishing attacks and other practices to improve users' experiences. These activities will help associates recognize and respond to any incidents independently. Besides that, the trainer team can incorporate gamified elements such as quizzes, crosswords, and rewards to make learning more engaging and enjoyable. Moreover, organizations could design posters which explain relevant issues that users may encounter at work such as receiving phishing emails, how to create strong passwords, and the correct way to use secured websites. These posters highlight those things that users need to do or keep in mind when they perform their daily tasks. It is important that employees continue to remember, visualize, and follow cyber-security best practice.

Monitoring compliance

Monitoring the level compliance achieved by the staff is a critical aspect of maintaining a robust cyber-security posture. Once the program has been implemented, processes must be put in place to monitor compliance and effectiveness. Larger organisations employ automated tracking systems that are designed to capture key information regarding program activity (e.g., courses, dates, audience, costs, and sources). The tracking system can also capture this data at a small-team level, so that it can be used to provide enterprise-wide analysis and reporting regarding awareness, training, and education initiatives (Wilson, Hash, et al., 2003).

Formal evaluation and feedback mechanisms are critical components of any security awareness, training, and education program. Continuous improvement cannot occur without a good sense of how the existing program is working. In addition, the feedback mechanisms must be designed to address objectives initially established for the program. A feedback strategy needs to incorporate elements that will address quality, scope, deployment method (e.g., web-based, onsite, offsite), level of difficulty, ease of use, the duration of sessions, relevancy, currency, and suggestions for modification (Wilson, Hash, et al., 2003).

Continuous improvement is an on-going process that focuses on creating a level of security awareness and excellence to achieve a pervasive security presence in the organization. The processes that deliver awareness, training, and education to the workforce should be integrated thoroughly into the overall business strategy. A mature security awareness and training program defines a set of metrics for this area, and automated systems should be in place to support the capture of quantitative data and the delivery of management information to accountable parties on a regular, predefined cycle. Finally, in this stage, agencies have incorporated into their awareness and training program formal mechanisms for ongoing research in areas of technology advancement, good practices, and benchmarking opportunities.

Enterprises should consider their IT budgets when planning, based on factors such as business size, business growth expectations, business performance expectations, the emerging business landscape, and the state of their current infrastructure. Alexandra Borgeaud, who is a research expert covering cyber-security and tech in Latin America, published on the Statista website that "On average, companies worldwide allocate at least 12 percent of their IT budget to information security. The highest share was distributed in 2020, at 12.8 percent. By 2020, companies allocated approximately 12.7 percent of their IT budget to IT security" (Borgeaud, 2023b, page 10) . Moreover, the article highlighted that "In 2025, small and mid-sized businesses (SMEs) were forecast to spend 29.8 billion U.S. dollars on managed security services. Overall, SMEs were expected to spend 90 billion U.S. dollars on cyber-security in 2025, up from 57 billion U.S. dollars in 2020. The regions with the highest anticipated spend are North America, the Asia

Pacific region, and Western Europe" (Borgeaud, 2023a, page 20)

CONCLUSIONS

The increasing complexity and frequency of cyber-threats necessitates robust cyber-security education and awareness programs, especially for small teams within enterprises. These teams often face unique challenges, including limited resources, varying levels of technical expertise, and the ever-present risk of underestimating cyber-threats.

This article has outlined several strategies to enhance cyber-security education and awareness for small groups. By developing tailored training modules, employing interactive and engaging learning methods, and continuously updating content to reflect emerging threats, organizations can equip their small teams with the skills and knowledge necessary to identify and respond to cyber-threats effectively. Furthermore, promoting a proactive security culture, enabling behavior change in cyber-security implementing practical security measures, and addressing resource constraints are crucial steps in building a resilient and security-aware workforce.

By focusing on these strategic areas, enterprises can significantly improve their cyber-security posture, ensuring that even the smallest teams are prepared to defend against cyber- adversaries. This proactive approach not only safeguards sensitive information but also enhances the overall resilience and security of the organization.

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Interview

From Eastern Europe to New Zealand Influential Business Transformation and Innovation Leader: A Leadership Profile of Aleksandra (Sasha) Skakun

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ABSTRACT

In a world where businesses must adapt rapidly to technological and market shifts, professionals like Aleksandra (Sasha) Skakun are redefining how transformation is delivered. Sasha's journey from Eastern Europe to New Zealand, and from operational project management to innovation leadership, is a compelling story of resilience, insight, and strategic action. With experience spanning manufacturing, IT, and industrial sectors, she combines technical acumen with a deep understanding of people and culture. In this interview, Sasha shares her views on overcoming resistance, shaping agile service delivery, harnessing emerging technologies, and building trust through empathy and results. Her story offers inspiration for aspiring change agents and a roadmap for organisations navigating today's evolving landscape of business transformation.

Keywords: Business transformation, Innovation leadership, Change management, People-centered leadership, Digital transformation.

INTRODUCTION

Aleksandra Skakun, known professionally as Sasha, is a leader in business transformation and innovation consulting in New Zealand. Her diverse career began in European manufacturing and evolved through software development and industrial IT service delivery. Sasha's strength lies in her ability to connect strategic vision with operational excellence, always guided by a philosophy that puts people at the heart of change. Since relocating to New Zealand, she has led significant transformation initiatives across multiple sectors, earning a reputation for driving sustainable, human-centred innovation. Her journey began long before her move to Aotearoa, and it continues to inform the way she approaches change today.

Aleksandra (Sasha) Skakun

"I see transformation as more than project delivery; it's a cultural shift. The true measure of success is when people feel empowered, processes become seamless, and value creation is sustainable."

That holistic view of transformation was shaped by Sasha's own journey. She explains that her relocation to New Zealand was born from a combination of strategic thinking and personal values. "We were initially looking at the UK, but Brexit disrupted that plan. Then Australia came up, but the climate felt off. New Zealand felt right, and it offered career growth, community, and a better work/life balance," Sasha recalls.

Upon arriving in New Zealand, she pursued a Master's in Applied Management while proactively preparing for the local job market. A strong planner, Sasha analysed industry trends, identified key skill gaps, and worked to make

herself employment-ready by the time she graduated. Her break came via a network referral. Despite some initial immigration hurdles, her perseverance and preparation paid off when she landed her first role. “The interview was short but effective. Navigating the paperwork and visa logistics was the hard part. It taught me that transformation, either personal or professional, starts with clarity and ends with commitment,” Sasha reflects.

In her early career, Sasha’s approach to project management was methodical, focused on timelines, delivery, and coordination. However, she often found herself asking, what happens after the project finishes? That curiosity led her beyond one-off projects into service delivery and, eventually, into the broader realm of business transformation. “I realised delivery is just one part. Real impact comes from rethinking the model itself; how services are designed, how they evolve with user needs, and how culture supports that change,” she reflects, emphasizing the need for a holistic approach to improvement.

Sasha’s adaptability has been honed across many industries, from factory floors to high-tech hubs. Early in her career at Heinz, for example, she worked closely with frontline manufacturing teams and learned to respect operational constraints. Later, in the software sector, she led agile transformations that shortened release cycles and improved responsiveness to customer feedback. In her more recent industrial projects, she has overseen complex system integrations that balance compliance, efficiency, and user-centricity. These diverse experiences, she notes, have each imparted valuable lessons: “Manufacturing taught me pragmatism: you learn fast that solutions must be workable. IT gave me speed and flexibility: how to pivot quickly, iterate, and co-create,” Sasha says.

Underlying all these experiences is a consistent focus on what Sasha calls her core framework of “people, processes, and platforms.” No matter the environment, “you adapt the proportions,” she explains, “but never lose sight of all three.”

Rather than adhering rigidly to a single framework, Sasha treats change methodologies as adaptable tools chosen to fit each situation. “ITIL, Agile, Waterfall: they all have value,” she says. “But success comes from choosing the right tool for the right job.” This pragmatic approach is coupled with a belief in frontline-driven innovation. Sasha insists that transformation starts with listening to those on the ground: “Your best insights come from people using the system every day.” One example of her people-centric approach was the implementation of a “shift-left” strategy in an IT service desk operation she led. In that initiative, Sasha empowered first-level support staff, refined issue routing logic, and instituted continuous feedback loops. The result, she notes, was more than faster resolutions: “We changed the culture of accountability.”

Sasha acknowledges that resistance to change is a natural part of any transformation. “It’s not about pushing through, it’s about listening, understanding, and co-creating solutions,” she says of her approach to overcoming objections. For instance, when introducing an automated computer imaging tool (Autopilot) at one organisation, she faced strong pushback from the IT team. Instead of forcing the change, she took a measured approach: “We paused, piloted with small teams, and showed the results. That transparency turned critics into champions.” She also makes a point to involve stakeholders at every level early in the process, mapping out whose voices need to be heard. After all, Sasha emphasizes, “people support what they help create” a philosophy at the heart of achieving sustainable change.

In measuring the success of transformation initiatives, Sasha believes in using data informed by dialogue. Key performance indicators such as first-call resolution rates or Net Promoter Scores are useful, but she views them as starting points. “KPIs like First Call Resolution or NPS are great, but they’re just indicators. I look for the story behind the metrics,” she explains. In one Asia-Pacific service desk project, for example, resolution times dropped by 40%, but the more significant result was a 25% increase in user satisfaction. To reach that outcome, Sasha recounts, her team

“built dashboards, ran feedback surveys, and celebrated wins.” In her view, such recognition “fuels momentum.”

Always looking ahead, Sasha stays attuned to emerging trends reshaping the business landscape. “Hyperautomation isn’t hype, it’s a strategic shift,” she notes, referring to the convergence of AI, robotic process automation (RPA), and low-code platforms that is changing how organizations operate. She views artificial intelligence as an augmentation to human decision-making rather than a replacement. “AI provides the insights; people make the decisions,” Sasha says, adding that “emotional intelligence and ethics can’t be outsourced.” Her strategic lens remains focused on applying new technologies to real business problems. She is careful to ensure that technology’s role is to simplify rather than complicate work, and that it empowers users instead of merely impressing stakeholders.

For Sasha, successful change leadership also demands continuous personal growth. “Transformation is personal,” she says, a principle she demonstrates by investing in her own learning through certifications, peer discussions, and mentor engagements. Every new perspective, in her view, adds value to her work. She likewise stresses the importance of building trust over time through consistency, humility, and delivering results. “Trust is built through consistency, humility, and results. That’s how you move from vendor to partner,” Sasha observes. It’s an approach that has helped her evolve from an external consultant into a trusted advisor for many of her clients.

Sasha’s story is one of purpose-driven transformation. Her ability to integrate technology with human insight, apply adaptable methodologies, and lead with empathy makes her a standout in her field. As New Zealand’s business landscape continues to evolve, professionals like Sasha provide not just the tools but the vision and trust needed to ensure change is not only implemented but fully embraced. Her journey from immigrating to Aotearoa to spearheading complex innovation initiatives illustrates how perseverance, lifelong learning, and a people-centric philosophy can turn the challenge of change into an opportunity for growth. Ultimately, her experience affirms that lasting impact comes not from imposing change, but from inspiring people to be part of it.

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Conceptual Article

Learning from the Lessons: Developing Experiential and AI-Safe Activities and Assessments for Tertiary Vocational Education

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ABSTRACT

This conceptual analysis of experiential learning is framed in the context of a recent Experiential Education Initiative at Auckland International Campus. Our study is based on emergent themes from student activities submitted by lecturers in Applied Management, Construction and IT. From this qualitative data, four key concepts of activity design (context, interaction, process, product) and four phases of learning experience (concrete experience, reflective observation, abstract conceptualisation, active experimentation) were identified. The article analyses each of these separately and conjointly from a pragmatist perspective aimed at informing the practice of lecturers, facilitators and activity designers in vocational tertiary education. Attention is given to the application of the above concepts and phases through a non-discipline specific enquiry focused on authentic activities and non-exam assessments which are, by virtue of their design, both AI-resilient and AI-tolerant, and thus deemed AI-safe.

Keywords: tertiary vocational education, experiential education, assessment design, AI-resilient assessment, AI-tolerant assessment

INTRODUCTION

In June 2025, Auckland International Campus (AIC) launched an Experiential Education Initiative to create a learning and teaching framework for the organisation and conduct a systematic review of all assessments across its campus. The underlying purpose of this initiative is threefold: 1) embed employability and work readiness more deeply within the organisation's culture; 2) develop new, varied and authentic learning activities and non-exam assessments that enable the "safe" use of GenAI and prevent its misuse by students; and 3) raise awareness of experiential education among students, lecturers and other staff. In due course, everyone at AIC should be able to benefit from well-integrated experiential education both in terms of the employability values it espouses and the vocational programmes it delivers.

This article reports on an activities survey which was conducted among lecturers to support the AIC initiative and provide material for the analysis of effective experiential learning in this context, with the aim of answering the following questions:

- What are the key features of good practice in experiential learning design?
- What common pitfalls are involved in designing experiential activities?
- What conceptual principles underlie effective experiential learning design?

After a brief description of the methodology involved, the study will outline its qualitative findings and exemplify the answers to these questions in accordance with the terms of its project approval from the AIC Research Ethics Committee. By addressing issues that relate to experiential learning both in theory and practice, we are hoping that our insights and recommendations will be of use to educators in Applied Management, Construction and IT, as well as tertiary vocational programmes more generally.

BACKGROUND

AIC has a vision of developing New Zealand's most employable graduates and its experiential approach to learning and teaching is central to the strategic planning and implementation of this vision. Its approach is based on a broad view of employability, as redefined by Oliver (2015, p.58) for the "disrupted economy" where "employment no longer necessarily means winning or keeping for the long term a traditional, full-time position in a company, organisation, small business or institution." This concept can be readily applied to the disruption brought about by the Covid pandemic and the advent of public AI. Oliver's proposal for graduate employability in such circumstances may be summarised as a) developing discipline-specific or work-related skills, b) as well as more generic (transferable) skills, and c) practising them in context d) in a way that promotes self-efficacy and self-awareness. Until now, this conception of employability has mostly been articulated at AIC in terms of Otago Polytechnic's Learner Capability Framework Polytechnic, 2021, aimed at providing evidence of work-readiness to supplement students' academic qualifications. The Experiential Education Initiative offers an opportunity to fully integrate learner capabilities such as communication, leadership, teamwork, independence, critical thinking, adaptability and resilience to the student experience and assessment of learning.

As an assessment design project, the initiative also allows for innovative solutions to the serious problem that GenAI now poses for the validity and reliability of non-exam assessments on which a great deal of vocational education depends. Whilst experiential learning as a pedagogical approach is open to different interpretations, its most appropriate version for tertiary level programmes at the AIC campus will be based on authenticity (Gulikers et al., 2004). Authentic assessment was not only recommended for employability skills but also, years before the availability of GenAI to students around the world, for ensuring academic integrity (Sotiriadou et al., 2019). As well as being work-related, well-designed authentic tasks in "contextual problem-based assessments" Ifelebuegu (2023, p.4) remain too complex and multi-layered for students to complete simply by means of prompt engineering. Conversely, the protection afforded by this type of design enables the use of AI for professional purposes in student assessment work. Hence the term "AI-safe" is used here to describe assessments which can resist AI misuse and tolerate legitimate AI use (Balducci et al., 2025).

Beyond safeguarding the security of its assessments, AIC will be endeavoring to grow a study environment where students are not only self-aware but able to articulate the role of experiential learning in their own personal and professional development. For this end to be realised, a co-ordinated campus-wide approach to the guidance and support of every learner from orientation to graduation will be required. Thus, as well as lecturers, learning support and employability, The Experiential Education Initiative will address other staff members whose work will be impacted in different ways. The Association for Experiential Education defines this approach as "a philosophy that informs many methodologies in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities" Roberts (2016, p.23). Whilst obviously generic, the definition can be refined and expanded for the purposes of AIC's initiative. Of particular importance here must be the nature of the engagement generated by means

of this philosophy, one in which the role of the educator is shared with learners and where students "purposefully engage" with each other in tasks and projects that mirror the collaborative environment of the workplace. Another point of interest from the AIC perspective is the inclusion of work-related communities of practice in the meaning of those "communities" to which students will contribute.

METHOD

As previously mentioned, a survey was conducted with academic staff to collect samples of experiential activities they had used in their teaching during the previous year. For the purposes of this survey, these were defined as work-related, face to face, group activities either modelled on real work practices or designed as interactive learning activities aimed at preparing students for real-world tasks and/or work settings (i.e. intended to feel like real work situations). The template for providing such activities included the course in which it was used, its main aim, its learning outcomes and a description of the activity itself. This was sent out on 9th June 2025 to all academic staff (in Applied Management, Construction and IT) and the final submission date was 26th June.

The next step was to analyse the qualitative data by conducting a thematic analysis (Braun & Clarke, 2006). We worked independently to code the activities in different colours every time a specific feature emerged. We then compared our results and discussed differences of analysis in order to identify how these could be resolved. Finally, once we had reached a consensus, all emergent features were grouped into different themes on the basis of their commonality. Throughout this process, we paid close attention to the alignment of course aims and learning outcomes with the detail of each description and relations between the stages of the activity. No assumptions were made about any gaps in the descriptions or about their potential for being adapted and developed into more experiential activities.

Having completed this analysis, we set about interpreting our data from a pragmatist rather than a positivist perspective. Pragmatism has been described as "focused on an attempt to identify what is practically useful" Newton et al. (2020, p.4) and "the view that reality can be changed for the better" Prochner and Godin (2022, p.7). As well as the rigour of scientific expertise, this is a philosophy which values the judgements and knowhow of the reflective practitioner (Schön, 1983). It is from this perspective that we looked at the data material that we had collated. By taking internal evidence into account and evaluating the degree to which the claims made in each description were substantiated, it was possible for us to address our research questions. We were able to identify good practice, common pitfalls and conceptual principles in effective experiential learning design.

ANALYSIS

Overall, the survey generated a very high level of response, with forty-one lecturers submitting eighty-three activities from fifty-three courses across all the campus departments combined, ranging from NZQA levels 5 to 9. These activities involved various forms of commodity, building or system design, calculation, data analysis, enquiry, consultation, evaluation, problem-solving, decision-making, report and other professional writing, project management, role-play or simulation. In all, eight themes or aspects of experiential activities were identified through our analysis, these being equally divided between activity design and learning experience (see Table 1 below). We labeled the themes according to the best terminology that we could find to capture their essence in each case, whether or not these terms were actually used by the survey respondents.

Table 1: Thematic analysis

Activity Design	Learning Experience
• Context • Interaction • Process • Product	• Concrete experience • Reflective observation • Abstract conceptualisation • Active experimentation

For a balanced picture of how these different aspects may contribute to experiential learning design, we are going to deal with each one in turn so as to 1) outline what it may consist of, and 2) report on good practice, pitfalls and further conceptual implications. The connection between experiential education and AI-safe assessment also needs to be brought out in relation to activity design, whether in terms of resilience and security, or tolerance and authenticity.

Context

Context includes scenarios, situations and audiences for a specific task that students are required to undertake. These may be real or hypothetical, depending on the nature of the activity. Some contexts are designed as complete and unchangeable, whereas others allow for individualised elaboration by students on the basis of their research and/or experience, for example during work placement. However, whether fixed or flexible, the context for student activity should ultimately specify in appropriate detail where, when, how, and why any given task is to be done, as well as who for (e.g. the organisation, the client, and the manager or colleagues directly concerned). Only then can the authenticity of the context be fully established. What is more, the number and continuity of contexts also have to be carefully considered. While the same context can be used for a wide range of creative, innovative, personalised outputs by students, differentiated contexts are usually needed with more standardised outputs, if only to discourage plagiarism and avoid academic integrity issues. Therefore, contextualisation for the same task needs to be equivalent across the student group to which it is given, and this equivalence must be maintained throughout a complex activity with multiple tasks. For our purposes, a further characteristic of a good context is that it should be "lived" in some way as part of the student's learning experience and not simply postulated in the abstract, whether through direct contact with industry, interaction with real-world experts, engagement with authentic situations, etc. The integration of this context to the activity process is likewise essential, as described below. Examples of good practice in our database revealed an awareness of some of the factors outlined above, notably those which promote integrity.

Meanwhile, AI-misuse and the dependence on GenAI can be prevented, at least to some extent, by limiting the context to local rather than national, international, industry-wide problems to solve, or perspectives to apply (Balducci et al., 2025). All too often, task designers draw from case studies which are widely available online or closely resemble such material. Safer strategies include the creation of new case studies (e.g. based on the designer's own professional experience) or inventing scenarios which involve physical and social realities in the learners' own environment. However, the main pitfall that we observed was a lack of authenticity overall. Although work-integrated learning in a real-life context is rightly regarded as the best way to enhance employability skills (Jackson, 2014), this does not mean that educational activities are necessarily inauthentic. It is possible to simulate the conditions, methods and workflows of a real work environment with varying degrees of authenticity in IT-design, construction planning or management strategising. As Gulikers et al. (2004) remind us, the authenticity of a task in relation to real-world practice is not an absolute but a matter of degree.

Interaction

It was explained above that context can be summarised in terms of where, when, etc. Interaction, on the other hand, relates to *who with* (as opposed to *who for*). This raises the question, first of all, about the mode of interaction through which the task is to be performed, i.e. independent work or teamwork. In a classroom (or blended) setting, this usually translates into individual work, pairwork or groupwork. It must be noted, however, that even independent work within an organisation is done for a colleague or entity such as a line manager or committee to whom the person doing this work is accountable. These relations can be replicated in various ways in class, involving the lecturer, other students, or an external party like another teacher or a guest lecturer. There are of course implications for assessed activities if any of these actors participate in some way towards achieving the task outcomes. A well-thought-out assessment rubric should always discriminate between the work of the person being assessed and that of anybody else involved. This also applies to assessment work undertaken within a team of some sort, so that individual student performance remains the focus of assessment. Examples of good practice that we noted included direct observation, tracking documents and individual responsibilities or outputs which could be used for the purpose of assessment. As for problematic attempts at groupwork, these tended to emerge from task designs which could be carried out more effectively by individual students and would not in fact be done collaboratively in the workplace.

An important distinction here is the one between cooperation and collaboration. Both are of course aimed at common objectives, but whereas a cooperative activity is divided into separate sub-tasks which are then allocated to different team members, a collaborative activity requires participants to be working more closely together on the same output throughout (Han & Ellis, 2021). Some form of task division is still needed so that students' individual efforts may be assessed, but now the process as well as the outcome should be taken into account, thereby making assessment more AI-resilient. Collaboration is also highly valued by employers as a capability (Polytechnic, 2021). Child and Shaw (2016) have devised a six-part framework for assessing this collaborative process, consisting of 1) social interdependence, 2) conflict resolution, 3) introduction of new ideas, 4) sharing of resources, 5) task division, and 6) communication. The application of a framework like this one necessitates that lecturers have been trained to use appropriate performance criteria when assessing individual student behaviour. A further implication is that, as well as behaviour, the framework offers a significant window for the assessment of personal attributes and soft skills or employment capabilities.

Process

If context provides both the purpose and rationale for doing an activity, and interaction clarifies the social setting in which this work is to be done, then the process defines how students are to proceed in order to reach the desired outcome. Bozkurt et al. (2024) see the shift to process-oriented education as more AI-resilient, while Moorhouse et al. (2023, p.493) emphasise its authenticity: "Allowing or even requiring students to use GAI [GenAI] at various stages of the assessment process would, in fact, enhance the authenticity of assessments." As a structural principle in assessment design, the process should be anticipated as fully as possible by the designer, even when a student task or project is conceived as flexible in the achievement of its final outcome. A well-planned process will contribute to the validity of this outcome and therefore of its assessment. The more complex the activity, the more its process needs to be detailed and elaborated for the achievability and realism of the work involved to be evaluated. Educators must also identify the skills and knowledge that are prerequisite as well as developed through each stage of the process and consider how these stages in a learning or formative activity are reflected in summative assessment. Finally, the

social and communicative interaction on which the process depends can only be effectively integrated and managed by advanced planning.

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The major problem we encountered was a lack of attention to this process, whether due to a lack of information on how students were expected to work on completing the activity, the assumption that this process was self-evident, or the belief that providing general instructions and task requirements would be sufficient to explain it. Judging from the data we collected, there seems to be a tendency to let the process "take care of itself" by means of unprompted student action and behaviour, except perhaps when circumstances require intervention by the lecturer concerned. As noted earlier, it is good practice to monitor and document student progress within group activities for assessment purposes. Productive task facilitation also requires the lecturer to manage the process in a supervising capacity, in a classroom (or blended) setting for the most part, so as to ensure that all students have the opportunity to reach a successful outcome. This entails knowing at every stage how each student is actively engaged and how their work will ultimately contribute to such an outcome being reached. Since no lecturer can be expected to do this from memory with a larger cohort, the use of technology becomes essential for recording and tracking individual performance. These are all strategies to ensure the implementation of a planned process that is intended to deliver the expected outputs. Following such a process will, in addition to the advantages previously mentioned, have the added benefit of minimising the risks of AI-misuse, just as the accountability and transparency of groupwork can impose limits on what an individual student may or may not do.

Product

The notion of product also emerged from our thematic analysis as output or outcome and even occasionally as result or consequence. It is important to note that what we have identified as a product here should not be confused with a marketable commodity, although it may sometimes be a commodity. It is simply the result of a process where humans act as participants, irrespective of this result being a physical thing (like a 3-D construction model), a virtual thing (like a website), or a performance (like a management consultation). But it is important to remember that in vocational education, a product needs to be more authentic than academic (apart from a few exceptions). It should resemble the kind of output that would be produced in a relevant work situation. Furthermore, in a well-designed activity, product and process are closely connected. What students produce needs to come about as the direct outcome of a clear and managed classroom (or blended) process that is purpose-made for generating the intended product, with or without the use by students of AI tools and agents. It was because they were explicitly related to a staged and practical, work-like process that the best examples of products in our database were both achievable and authentic, as well as AI-safe.

One distinct problem with a number of products in the activities submitted for the survey was their overly academic approach to the realities of contemporary practice in their field. As noted earlier, however, the main issues in activity design arose from the evident lack of attention to process. As well as creating opportunities for academic misconduct in all its forms, this obvious neglect also raises the concern of potentially insufficient skills development and employability training in generating the required output. The ability of students to get results from engaging in cooperative or collaborative work depends on their trust and confidence in the corresponding process. Active learning in experiential education is aimed at shaping a direct and lasting awareness of how things are done, or can be done, and not simply at the doing of those things. Whilst independent-minded students are often able to learn from unstructured activity, their autonomous approach and freedom from teacher dependence does not in itself guarantee a successful outcome. As for more dependent students who are used to didactic forms of teaching, they are likely to seek out easy and quick-fix solutions to the problem of producing the deliverables that are demanded of them. All in all, requesting products without training learners to participate in relevant processes will not greatly enhance their employability.

Learning experience

The themes of learning experience are the four phases of the Kolb cycle (Kolb, 2015), namely: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. This was the only model of experiential learning which was explicitly used by lecturers, many of whom drew from the terminology above. Kolb himself describes the experiential learning process as follows Kolb (2015, page.51):

> Immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for actions can be drawn. These implications can be actively tested and serve as guides in creating new experiences.

While concrete experiences can be variously interpreted, for the purposes of active learning in a vocational classroom (or cohort) such experiences will consist of student-centred work-related tasks. For these to be meaningful in the context of learning experiences, they should be pitched slightly above the students' current level of knowledge and competence to ensure a successful but imperfect outcome that could be improved. Lecturers will be able to gauge

from their initial needs analysis and their knowledge of student or class profiles whether and to what extent the tasks themselves will need to be scaffolded. These may either be focused on the production of one or more outputs (such as a SWOT analysis, a construction cost breakdown, or an ERD diagram), or may in fact be more of a by-product than the central focus of the activity (e.g. meeting notes, information tables, brainstorming flip charts).

Depending on the learning outcomes and objectives of the course, the subsequent reflective observation may address multiple aspects of this initial task, in terms of its process, its product, interpersonal relations, etc. Reflection can also look forward as well as back, encouraging students to think about how they would do the task differently in future, or even how it might contribute to a greater outcome (like a project goal, for instance). But one important factor to remember when designing a reflection stage in an activity is that students cannot be compelled to reflect. Just telling them to "think about" something is not enough to guarantee that post-activity discussions will be sufficiently focused to be useful. On the other hand, providing too much guidance with questions to answer or forms to complete might simply result in teacher-led reflection as opposed to independent thought. What is needed is one or more structured opportunities for reflection where students have the freedom to make up their own minds about what has been experienced in a way that is constructive and helps them to learn from doing an activity in the first place.

Whether it is a full-blown academic theory, a set of related concepts or an operational model, the nature of abstract conceptualisation must be understood as a progressive continuation of what came before. In the quotation above, Kolb describes the link between this phase and the preceding reflection as one of assimilation and distillation into concepts or abstract ideas. Here, continuity is essential to the learning process. Whereas abstract theorising merely consists of words (or symbols, images, etc), what is most innovative about experiential learning is that such abstractions are introduced after, and not before, an activity. This practice-first approach may be counter-intuitive to people whose whole education was built on theoretical foundations. Language itself appears to exclude the possibility of a reverse order, since we talk about theory and practice but not practice and theory. The pedagogy of theory-first education rests on the assumption that practical activity cannot be understood for what it is without a theoretical filter. In simple terms, learners need to know what is being experienced in order to understand it. Yet, although seemingly reasonable, this assumption does not take into account the fundamental purpose of human action, which is not necessarily about gaining understanding. We tend to do things in order to get results. Practical activity can therefore be quite meaningful to learners provided its objectives are clearly established. What subsequent theorising can do is to broaden and generalise that meaning, so that new knowledge may be deliberately applied in future. The main reasons for proceeding in this way, meanwhile, are two-fold: motivating students to learn, and narrowing the field of potentially relevant theory, thereby reducing the cognitive load.

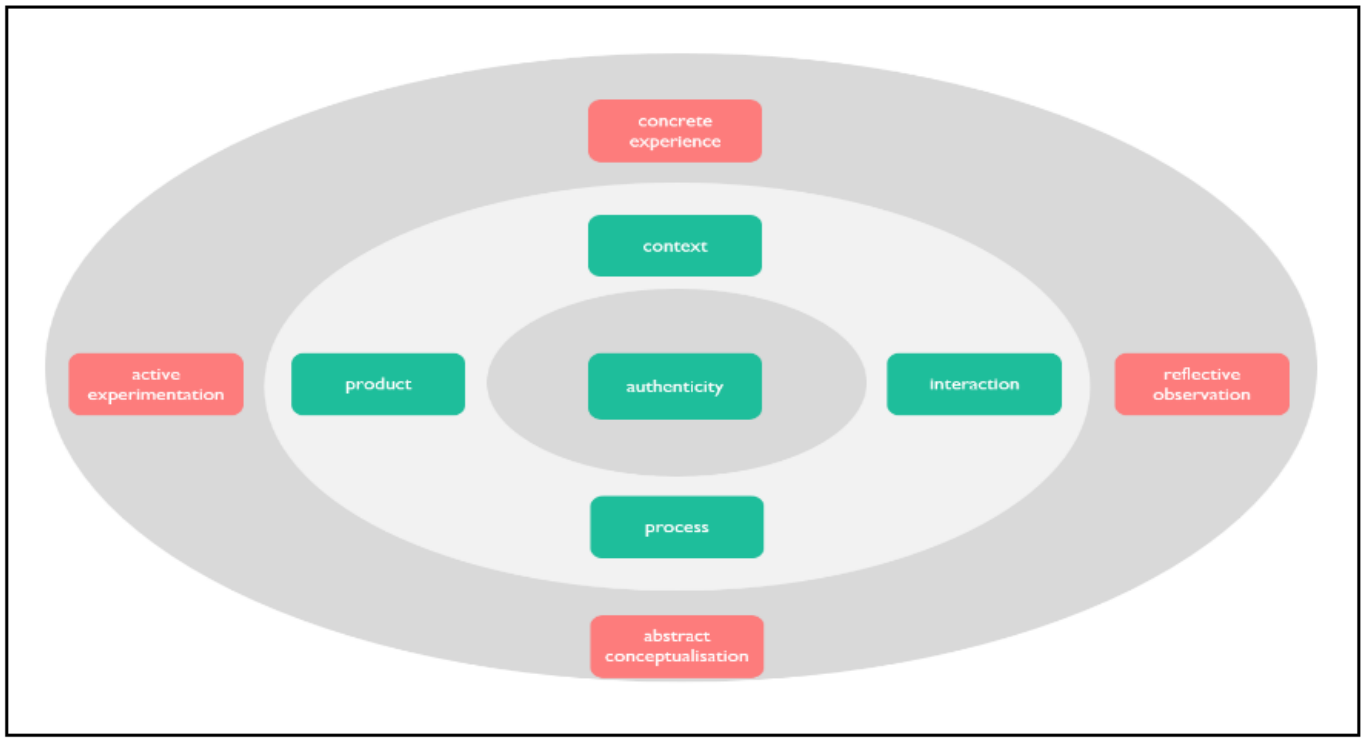
As the final phase of the learning cycle, active experimentation can be seen as revisiting the original activity or doing something new – a return or a departure. In either case, the aim is for learners to understand their experience in a new light. Their progress may be moderate or extensive, depending in part on the scope of the activity and its relation to a wider sequence within the course or programme, but learning remains as cumulative as it is in more traditional forms of education. What is different about it, in addition to the sequencing, is the greater opportunity for trying things out. By prioritising practice, educators can also valorise the importance of mistakes, misconceptions and false starts in the learning process. Overall, practice-first enables learning to become more memorable. It will also be apparent this approach at once demands and fosters greater levels of engagement from learners, or at least a different attitude to their own learning. Qualities like autonomy, adaptability and resilience now come to the fore.

In the best activities from our survey, each phase of the Kolb learning cycle was included in a separate stage with

a different sub-aim, and all the phases were fully integrated into a coherent and progressive whole designed for achieving the main aim(s). Above all, it was immediately apparent from the linking of ideas in the lecturer's description that students would benefit from a work-like, vocational focus throughout, leading to the achievement of useful outcomes. At the other end of the scale were activities in which the use of terminology (such as references to concrete experience or just experience or reflection or the application of learning) did not really seem to be warranted by the description provided. In other words, there was no clear evidence that the language of experiential learning had been used appropriately. Where there was experiential validity in the work done by students, this might in fact be limited to parts of the Kolb cycle that featured as discrete, standalone tasks. Some descriptions listed experiential things for students to do without explaining how these would be connected. Others tried to link them together without any thought given to the context, or the process, or the product, or all three. Mention was made of establishing a theoretical grounding without prior experience or reflection. Students were described as actively applying their learning, not by means of tasks with specific outcomes and tangible outputs, but simply through general topic-based discussion.

More than anything, what seemed to be missing from significant parts of our data was a clear indication that experiential learning activities are most likely to be aimed at real-world problem-solving (or difficult issues to be addressed). As noted earlier, well-designed authentic tasks are problem-based (Ifelebuegu, 2023). From the perspective of the Kolb cycle, such an approach to activity design would help lecturers to identify appropriate learner experiences within their field of subject matter specialism. Instead of establishing foundational knowledge for teaching their courses, they could investigate current business or industry needs through credible sources in order to develop relevant case studies or other problematic situations that stand in need of resolution. A typical design for a student activity would start by attempting to deal with this problem, then to reflect on this initial attempt, then to

Figure 1: Activity Design and Learning Experience



generalise from personal reflection, and finally to apply what has been learned to the same or a similar problem or issue. Figure 1 provides an overview of these learning phases in conjunction with the key concepts of activity design.

CONCLUSION

Experiential education in a tertiary vocational context is built on a concerted effort by all parties involved to engage in appropriate, work-related or work-based activities in a learning cycle where different skills and types of knowledge are prioritised according to the relevant learning outcomes and objectives. Complex, multi-layered activities are generally more suitable for these purposes both from the point of view of authenticity and resistance of AI-misuse or tolerance of legitimate AI use. To ensure that such levels of complexity and AI-safety are achieved, it is recommended that context, interaction, process and product are applied in sufficient depth and detail in the design of activities. Meanwhile, for students to gain memorable and useful learning from their education, it is also advised to integrate all four phases of the Kolb cycle so they may be empowered to make use of what they have learned in new and unpredictable ways in the future.

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Reflection

Beyond the Diagram: Structured Reflection and Peer Feedback in Novice Software Design Learning

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ABSTRACT

Teaching abstract modelling specifically class and entity relationship diagrams remains a persistent challenge in undergraduate computing. Even in project-based courses focused on providing hands-on experience, beginners frequently replicate patterns, complicate models unnecessarily, or incorrectly apply relationships without explaining the reasoning behind their decisions. This opinion piece discusses our experiences in teaching database and software design in two first-year courses and describes a simple pedagogical intervention implemented between the requirements analysis and the individual diagramming stages. This approach consist of four main structured stages: Scenario Analysis, Peer Review, Reflection and Diagram Construction. Although this is not a controlled study, our reflections indicate that incorporating early peer review and reflective practices can help novices shift their emphasis from "what belongs where" to "why this abstraction exists," ultimately enhancing the quality and communicative effectiveness of their diagrams. We present practical suggestions for educators to integrate this approach into similar courses that require teaching design specifically for novice students.

Keywords: Computer Science Education, *Reflective Learning*, *Peer Feedback*, *Software Design*

INTRODUCTION

Software design is a fundamental element of the computing curriculum, yet effectively teaching it, specifically to novices remains a significant challenge (Batra, 2007; Katz & Shmallo, 2016). Design diagrams such as class or entity relationship diagrams require learners to combine their understanding of the domain, abstraction skills, and the conventions of notation. Although activity-based learning and real-world examples are popular in in teaching this domain, many novices still tend to approach design tasks with superficial reasoning, replicating familiar patterns without fully grasping the underlying principles guiding their decisions. This gap is important: When students view diagrams as mere decorative elements instead of interpretive models, it adversely affects the later stages of implementation, testing, and maintenance.

This paper discusses a recent intervention in the classroom that led to significant improvements in student engagement and comprehension of software designs. This intervention is rooted in reflective practice and collaborative learning concepts (Schön, 2017; Topping, 1998). While the change we did was small, it has a substantial impact on how students approach their learning. Instead of allowing students to move straight from requirements analysis to individual diagram creation, we incorporated a short, structured checkpoints where learners articulated their reasoning, examined different abstractions, and provided specific critiques prior to finalising their designs. The goal was not to increase the content but to alter the timing and manner in which understanding occurs.

The study is situated in two first-year studio courses offered at a Polytechnic in New Zealand, in which students developed both database and software designs to integrate into their project implementations (Hewage & Imbulpitiya,

2025). These courses emphasises a collaborative learning environment with hands-on experience, and despite this supportive nature, students find it difficult to work with these abstract models. This often leads to overcomplicating the models, misapplied relationships, or treating notation as a checklist rather than a language for articulating design decisions. Our intervention addresses this particular challenge in the learning process.

This article is a collective reflection on our experience teaching software design, highlighting the methods we employed throughout the teaching process. Presented as an opinion piece instead of a formal study, it extracts practical insights from our classroom experience. We aspire that the lessons shared here will assist educators and instructors in related fields to reassess elements of their instruction in teaching software design for novices.

The remainder of this article is structured as follows. The next section reviews existing work in this research domain. We then describe in detail the intervention applied in the teaching process. Finally, we present a discussion of our findings and conclude the paper.

LITERATURE REVIEW

Cognitive complexity in software design

Grasping the numerous interrelated abstract concepts in software design poses a well-recognised challenge for beginners (Amin et al., 2019; Katz & Shmallo, 2016). In a standard introductory software design course, students must quickly comprehend various concepts such as requirements analysis, conceptual modelling, design principles, and implementation factors. These concepts typically do not function independently; rather, they are best understood in relation to one another. For example, creating a design model requires not only familiarity with the relevant notations but also a clear understanding of the essential requirements, an anticipation of implementation challenges, and a consideration for maintainability. This interconnection results in a complicated learning environment where understanding individual topics in isolation does not suffice for proficient performance.

Software design is fundamentally an interactive learning area, where the concurrent handling of numerous interconnected components creates a significant intrinsic cognitive burden (Sweller, 1988, 2010). For beginners, this burden can impede the development of strong mental models that bring together procedural knowledge (how to implement techniques), declarative knowledge (what the concepts signify), and conditional knowledge (when and why to apply particular methods). Consequently, learners frequently find it challenging to ”think like designers,” lacking the conceptual synergy that experts utilise to assess trade-offs, foresee subsequent effects, and make well-informed design choices. Previous studies in software engineering education have indicated that these challenges are not confined to a particular design subfield—like databases or user interfaces—but are widespread throughout the overall design process due to its cognitive demands (Batra, 2007; Katz & Shmallo, 2015).

In light of these challenges, educators have investigated a range of pedagogical strategies designed to minimise unnecessary cognitive burden while encouraging deeper conceptual relationships. Approaches such as pedagogical models, work examples, scaffolding, and visual modeling tools have proven effective in managing complexity and making abstract ideas more understandable (Katz, 2018, 2020; Katz & Shmallo, 2016; Watson, 2006). Nevertheless, while these techniques facilitate knowledge acquisition, they often do not directly prompt learners to reflect on their thinking processes or acknowledge the evolution of their understanding over time. This is where reflective learning adds another layer: by encouraging students to express their reasoning, assess their design choices, and link new understandings to existing knowledge, reflection can aid in solidifying mental frameworks and enhance the application of learning in new situations. Therefore, in the realm of software design education, incorporating

reflective learning into teaching methods offers a means not only to alleviate cognitive overload but also to cultivate the metacognitive abilities critical for developing design proficiency.

Reflective learning as a pedagogical strategy

Reflective learning is a teaching approach where students actively consider, evaluate, and comprehend their own learning and experiences (Moon, 2013; Schön, 2017). Reflective learning asks students to stop and critically consider their assumptions and decision-making processes, rather than focus only on the acquisition and application of technical knowledge. This kind of reflection, which aims to bring hidden ideas to the surface, can take many different forms, including written journals, reflections following tasks, design justifications, or organised conversations. In software design, reflective techniques allow students to document their design choices and the rationale behind them, establishing the foundation for deeper understanding.

In terms of cognitive load, reflective learning can assist in managing the inherent complexity of software design by allowing learners to decompose complicated tasks into smaller, more manageable parts. By expressing their thought processes, students can articulate and structure their mental models, which helps to relieve working memory and aids in the development of schemas (Sweller & Ayres, 2011). Furthermore, reflection promotes progressive integration of concepts in which learners revisit previous ideas in the context of new understanding, thereby reinforcing the links between related topics. This repetitive process reflects the method of an expert designer who continually evaluates decisions against changing constraints, requirements, and design principles.

Peer feedback in learning

Peer feedback is a collaborative learning approach where students assess and offer constructive critiques on their peers' work, usually based on a defined criteria (Topping, 1998). In computer science education, peer feedback has been demonstrated to improve conceptual comprehension and participation (Turner & Perez-Quinones, 2009), strengthen learning in visualisation classes (Beasley et al., 2020) and enhance self-regulated assessment and motivation in software engineering (Groeneveld et al., 2020). A recent meta-analysis corroborates these beneficial effects across various computer-based learning environments (Li et al., 2024).

In design education, peer feedback fulfils multiple roles: it introduces students to various approaches, encourages critical analysis, and helps them internalise standards of quality. By reviewing a classmate's design, learners must use the same evaluation criteria they apply to their own work, which deepens their understanding of the design process. This evaluative exchange also fosters a sense of ownership over their learning, as students actively contribute to each other's growth rather than relying solely on instructors for feedback. More recently, researchers have utilised this specifically in database courses. A recent study conducted in an introductory database course investigates team-based peer reviews (Catania et al., 2022). In this study, participants apply a cooperative methodology where teams review one another's design artifacts as part of final design activities. This approach extends peer feedback into the design domain and promotes richer conceptual discussion.

Since both reflective learning and peer feedback have been identified in the literature as effective techniques for learning abstract and complex concepts such as designing, we attempted to combine both strategies in our teaching approach. The aim was to investigate how this integrated approach could support novice learners in software design by reducing cognitive load, enabling progressive conceptual integration, and fostering the metacognitive skills needed to develop design expertise.

THE INTERVENTION

Through our experience in delivering courses that incorporate conceptual design elements, it has become clear that many students find it challenging to grasp the abstract concepts needed to finalise their designs. This difficulty also applies to some of the students who are technically proficient. Recognising the complexities involved in the design process, we have experimented with various strategies to enhance students' comprehension of this process. As we explored different methods, we discovered that a significant factor in the students' struggles is their lack of reflective practices, which involve reviewing their actions, experiences, or learning to find meaning in them. Reflection encompasses more than mere recall; it involves analysing, questioning, and linking experiences to enrich understanding. Although we anticipate that the students will reflect on their learning, it has not occurred without explicit intervention. Consequently, we have introduced design activities that incorporate a mandatory reflective component, requiring students to complete this step to finish the activity. This revised approach introduced a four-step process, explicitly incorporating peer feedback and reflection before students committed to their designs.

The following is the process followed in the Entity Relationship Diagram (ERD) design activity according to the proposed revised approach.

Step 1: Scenario Analysis - Students analysed their selected project topics to identify entities, attributes, and relationships in groups. They extracted candidate elements and constructed a logical draft ERD based on their findings.

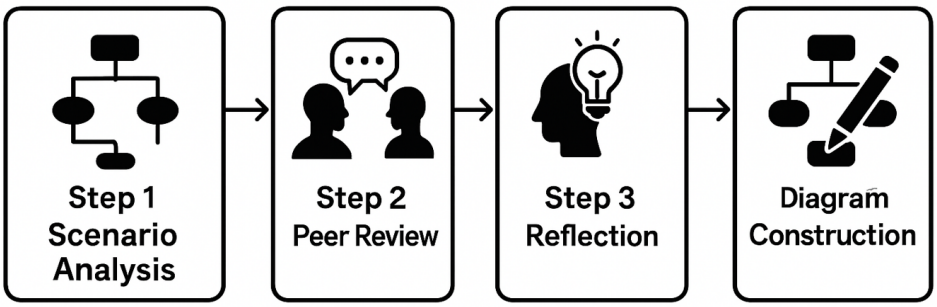
Step 2: Peer Review - The groups exchanged their draft ERD, visited the work of other groups, and provided structured feedback guided by specific review questions.

Step 3: Reflection – Students reviewed and reflected on feedback received from other groups. They critically evaluated the comments, discussed their assumptions, and revised their logical ERD designs accordingly.

Step 4: Diagram Construction - After reflection and critical evaluation, students finalised the logical ERD design, ensuring that the entities, attributes, and relationships were accurately modelled.

The Figure 1 represents the four main stages of the proposed approach.

Figure 1: A structured four-step learning process



This staged method intentionally allows students to incorporate reflection into their learning process. In Step 1, students start by examining their own beliefs about the issue at hand, which promotes self-awareness and enhances critical thinking skills. Step 2 brings in diverse viewpoints through peer review, motivating students to evaluate their reasoning against that of others and to acknowledge different strategies. In Step 3, guided reflection enables students to thoughtfully assess the feedback they have received, prioritise between constructive and less helpful feedback, and link theoretical concepts with practical application as they enhance their designs. Ultimately, Step 4 wraps up this reflective journey by converting insights into a more refined and precise logical ERD. Hence, the activity not only

navigates students through the technical components of database design, but also fosters the reflective practices essential for deeper understanding, flexibility, and ongoing growth. Please refer to Appendix 1 for the complete lesson plan of this activity.

Following the success of this intervention, we adopted a similar structured method for another course on software design, particularly focusing on the creation of class diagrams. Understanding that students faced similar challenges when moving from abstract problem descriptions to actual class structures, we modified the four-step process for this new setting.

In this activity, students initially participated in scenario analysis, where they investigated a specific problem domain to identify potential classes, their attributes, and possible methods. This phase encouraged them to extract and organise crucial information, forming a solid groundwork for informed design choices. During the peer review segment, groups shared their preliminary findings and offered structured feedback. This process allowed students to question themselves and re-evaluate their assumptions and design decisions to identify areas for improvement. In the reflection phase, students thoughtfully reviewed the feedback they received, engaged in discussions about improvements within their groups, and updated their findings accordingly. Lastly, in the diagram construction phase, they integrated these insights to create their initial class diagrams with enhanced clarity and confidence.

This approach allowed students to incorporate reflective practices into their learning process, progressing from technical skills to a more profound comprehension of software design choices. Similar to the ERD activity, students expressed increased confidence in expressing their design decisions, showed greater clarity, and demonstrated an improved ability to justify their modelling choices.

Moreover, the structured design provides the lecturer with natural opportunities to intervene and offer guidance. At each stage the lecturer can monitor group progress and step in when students appear stuck or uncertain. Such timely interventions not only help to resolve misunderstandings but also model effective problem-solving strategies, ensuring that students remain engaged and supported throughout the learning process. Although this sequencing delayed the construction phase slightly, the additional time devoted to cognitive rehearsal and social learning proved valuable. Students demonstrated clearer articulation of their design decisions and displayed greater confidence in explaining and justifying their diagrams.

DISCUSSION AND CONCLUSION

This intervention demonstrated how including scaffolded peer review and reflection into the design process significantly enhances students' learning outcomes beyond mere technical competencies. While the produced diagrams still required refinement to reach industry standards, the enhancement in clarity of the students' thought processes and the intention behind the design was striking. Most importantly, students started to demonstrate more advanced skills that go beyond merely creating accurate models demonstrating an understanding of the principles rather than fixating on the rules of drawing diagrams. Moreover, their design rationale was based on peer interactions. This suggested that the provision of collaborative feedback led to more richly justified design decisions. In addition, students were more confident than before in explaining their decisions and the associated constraints, indicating a shift from passive to actively taking part in the learning process.

Structured peer review proved to be especially effective. If peer interactions are well planned, guided, and adequately supported, it creates a low-pressure environment for students to explore ideas, recognise misunderstandings and embrace different viewpoints (Liu & Carless, 2006). This indicates that social aspect of learning which could be often overlooked in courses with technical emphasis, can act as an important link between theoretical understand-

ing and practical application. Specifically in tasks that require the understanding of abstract concepts like software design.

As educators, we were particularly impressed by the meta-cognitive advancement this approach facilitated. Students not only acquired knowledge on how to design but also started to recognise the significance of their design choices a vital distinction in cultivating reflective practitioners. This underscores the importance of deliberately integrating reflection as a key component of design education rather than expecting it to develop naturally.

The outcomes of this intervention align with earlier research that highlights the importance of reflection in enhancing deep learning and conceptual understanding(Moon, 2013). By incorporating structured opportunities for critique and guided reflection, the activities addressed common challenges faced by novice designers, specifically their tendency to focus on syntactic accuracy rather than conceptual understanding and their hesitation evaluate their own work (Batra, 2007; Katz & Shmallo, 2015). This observation reinforces the idea that participating in reflective practice not only results in producing improved artefacts but also fosters the cognitive skills necessary for sustained professional development.

The findings of this study reveal a number of practical approaches for educators seeking to design effective learning activities around abstract concepts:

- **Prioritise reflection before design:** Place reflection and evaluation ahead of design deliverables to establish a strong conceptual foundation.
- **Structured peer interaction:** Provide scaffolding to ensure feedback is constructive and promotes critical engagement.
- **Emphasise justification over output:** Motivate students to articulate the reasons for their design choices instead of merely showcasing technical skills.

As the field of computing education evolves rapidly, it is important to comprehend that reflective practices are fundamental in learning than supplementary. By incorporating peer review and guided reflection at the beginning of the design process, abstract and often intimidating tasks can be transformed into opportunities for genuine comprehension and professional growth.

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Appendix - Lesson Plan - Week 6 (Session 2)

Course Name	Studio 1 (Level 5)	**Date**	05/06/2025
Lesson Topic	Entity Relationship diagram (ERD)	**Lesson length**	65 minutes

Relevant Course Learning Outcomes:

Redacted

Lesson Objectives – by the end of this session, the learners will be able to:

1. Collaboratively design a logical ERD.
2. Review a logical ERD created by someone else and provide constructive feedback.
3. Review and reflect on the feedback received on your ERD and construct the final diagram.

Task purpose *(this will clearly align with Lesson Objectives)*	**Task procedure – what the teacher is doing**	**Task procedure – what the learners are doing** *(include interaction patterns: T-S/ T-Ss/ Ss-Ss/ S-S/ S-T)* [1]	**Output**	**Time & Duration**
Refreshing the memory of the concepts that they have learnt so far. The task is to create the logical ERD for their group project. This is a group activity. Groups are pre-formed with 3-4 students.	Interact with students to refresh their understanding of previously learned concepts. Some generic questions related to ERDs will be asked to make sure students are confident on the task. Sample questions: *What is an ERD? what are the main components of ERD? How many types of ERDs are there? What are they?* Explaining the purpose of the task and how it's directly related to their final project.	***T-Ss-T***: Involve in the discussion and answer to the questions ***T-Ss***: Listening to the instructions provided by the lecturer to understand the task clearly and how It directly related to the project. ***S-T***: Asking questions to clarify any doubts or understand the task better (If any).	No Concrete output	10 min
Completing the **step 1** of the activity: **Scenario analysis**	Walking to every group and checking the progress. *(is everyone actively engaged in the discussion? has someone taken the responsibility to draw the ERD on the paper etc.)* Making sure and encouraging all the students to actively engage in the activity. *(Ask a few specific questions about the tasks or ask them to explain a relationship or reason behind making a certain choice etc.)*	***Ss-Ss***: Analyse the selected topic to identify entities, attributes and relationships. ***Ss-Ss***: Draw the draft **ERD** on the paper provided based on the discussions. Further discussions may need in deciding relationships. ***S-T/Ss-T***: Asking questions or asking for support when needed to complete the task successfully.	Logical ERD on paper	15 mins.

[1] T-S: Teacher to student, T-Ss: Teacher to students, Ss-Ss: Students to students, S-S: Student to Students, S-T: Student to Teacher

Task purpose *(this will clearly align with Lesson Objectives)*	**Task procedure – what the <u>teacher</u> is doing**	**Task procedure – what the <u>learners</u> are doing** *(include interaction patterns: T-S/ T-Ss/ Ss-Ss/ S-S/ S-T)* [1]	**Output**	**Time & Duration**
Completing the **step 2** of the activity: **Peer Review** Students are expected to visit other groups and provide feedback on their ERDs	Instructing students on how to move from table to table. Check the time and instruct them to move to other groups if they spend too much time on one group	***Ss-Ss***: Each group will go to all the other groups according to the instructions, check the ERDs (entities, relationships, attributes) and write down their feedback (use a different colour pen). *(Are all relevant entities included? Are the relationships accurately created? Are any important attributes missing?)*	Papers with the comments from other groups.	15 mins.
Completing the **step 3** of the activity: **Reflection** Everyone will discuss and reflect on the feedback provided stories from other groups	Instructing students to review feedback provided by other groups and reflect/critique on that. *(Is it relevant? Does it help improve your design? Should you adopt it or not? Justifications of decisions made)* Leading the discussion whenever needed. Check the time and instruct them to move to other groups if they spend too much time on one group	***Ss-Ss***: Discuss and reflect on the feedback provided by other groups. Explain the decisions to the class. Explain why they chose to adopt or reject each suggestion.	Decisions and justifications related to the peer feedback.	15 mins.
Completing the **step 4** of the activity: **Diagram Construction**	Instructing students to update their logical ERD based on the review and reflection decisions.	***Ss-Ss***: Update the **ERDs** based on the decisions made during the reflection.	Final logical **ERD**	10 mins.

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Educational Guidance

Writing Experiential Assessment Rubrics

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INTRODUCTION

These guidance notes were developed during the current review of assessment practices at Auckland International Campus (AIC). They are based on the work undertaken so far by four lecturers in AIC's Experiential Education Initiative working group, whose project is aimed at redesigning assessments in Applied Management, Construction and IT in order to make them more experiential and better suited to the development of employability skills. While the assessments themselves are discipline-specific, the guidance notes from the project are intended to be applicable in other vocational fields of tertiary education. Hence, they do not include technical jargon or non-educational terminology, nor do they provide guidelines or tips for writing standard academic assessment rubrics at any level. The focus throughout remains how to write such rubrics from an experiential perspective.

Experiential learning is based essentially on learning through doing and reflection (Moon, 2004) Consequently, the assessment of experiential learning should be more concerned with what students do or have done for a particular purpose than with what they think or believe about a general topic or question. Their activity will consist of actions taken, processes or procedures followed, choices and decisions made, problems solved, resulting in work for assessment being completed (whether it be a text or video, an artefact, etc) or an assessed performance being given (a presentation, interview, etc), or a combination of both. In the vocational sector, such tasks need to resemble the kind of work or performances undertaken in the workplace. Any suitable context in which they would normally be done in the real world will provide a *criterion situation* (Gulikers et al., 2004) which sets the standard against which student work or performance can be assessed. If it is to be at all experiential, vocational assessment therefore needs a context that is similar to an appropriate criterion situation, as well as criteria for evaluating how tasks have been completed or performed which would be considered valid in such a situation. The feedback given to students will likewise need to be grounded in relevant professional practice, in alignment with the rubric.

DESIGNING AN EXPERIENTIAL RUBRIC

So how to write these criteria? In view of the diversity of possible criterion situations, it would be pointless to follow a fixed recipe or employ a prescriptive technique. A task may only be assessed on the specific merits afforded by its context. However, certain principles or guidelines may be of use to the assessment writer.

1. **Decide what type of grading scheme you will adopt.**
   A *competency-based*, pass-or-fail approach(Wambui, 2024) has often been preferred for the real-world application of skills. On the other hand, grading bands can provide a more fine-grained assessment of complex tasks. It is also worth noting that employee performance in industry tends to be measured by means of a rating scale.

A third option might be a combination of both methods. But there might also be institutional constraints either preventing or limiting the use of one or the other.

2. **Identify what you would accept as a pass.**
   Regardless of your grading method and the layout of your assessment rubric, the best starting point is to define what degree of proficiency would be acceptable (as opposed to not acceptable) in the criterion situation. Here the assessment writer may rely on their own experience of such a situation, or that of their colleagues, or draw from any relevant research that might be available. But regardless of how it is defined, the required standard for a pass, or a minimum pass grade, should be realistic as regards actual achievement or behaviour in the workplace.

3. **Don't assume pass criteria are less challenging to write.**
   In a banded grading scheme (such as 10-9, 8-7, etc), the minimum pass grade will outline the basic requirement(s) in relation to the criterion situation. Nevertheless, the language that best fits the descriptor for this band may not be any simpler in its vocabulary or syntax than that of the higher bands. It might even be more intricate. There is no reason why describing what is acceptable should be any easier from a linguistic point of view than describing what is outstanding, or what could lie in between.

4. **Use "and/or" in your criteria for below-pass grades.**
   Once a minimum pass grade is defined, the grading band below it can be seen as its negative formulation, so that what is deemed unacceptable can be readily identified and understood in contradistinction to its positive counterpart. Having said that, the student's work or performance may be assessed as below standard for not meeting the pass criterion to some extent, although not in every respect. This can be clearly indicated by using the double conjunction and/or to separate the descriptor into constituent parts, so that failure to meet one or more of these would prevent the student from passing the criterion as a whole.

5. **Avoid formulaic phrases from templates.**
   As regards the other grading bands, the rubric writer is advised to think carefully about how best to convey the degree of proficiency that is looked for in each case with direct reference, if possible, to the wording of the descriptor for the minimum pass. On the other hand, applying formulaic phrases and sentence patterns across different grading bands may lead to false distinctions (e.g. between *comprehensive* and *detailed*) or insufficient clarity for distinguishing between grades (e.g. between mostly and generally). The safest approach is probably to ask of each descriptor: *What would this work or performance look like in real life, i.e. in the criterion situation? How would you know that it matches this descriptor and not another grading band? What would be the distinguishing features?*

6. **Keep improving your band descriptors.**
   Like most forms of writing, assessment rubrics emerge from a recursive process. Without prior experience, the writer is unlikely to produce a one hundred percent effective rubric for a given task in a single draft. Fine-tuning occurs by setting one descriptor against another to see not only how they might differ, but how accentuating differences could help to refine, or even redefine, distinctions between grading bands. Yet throughout this process, it must be remembered that only the criterion situation can help you to determine whether or not a rubric is ultimately fit for purpose. In other words, it is the judgement of professionals in a real-world *community of*

practice (Wenger, 1998) and not simply traditional academic standards, that should be described in experiential assessment criteria.

7. **Stay focused on the criterion situation.**
   Traditional assessment rubrics are designed for the kind of academic work which students normally do in their studies, but experiential assessment rubrics are written for a different purpose. While they share a number of characteristics with more traditional rubrics, their point of reference will be the criterion situation, which is itself defined and determined by a specific community of practice beyond academia (unless standard academic practice happens to be the targeted professional skill). The defining purpose of an academic rubric is to assess the student's knowledge and understanding of the course content in relation to its discipline. The purpose of a vocational experiential rubric is to assess the student's ability to function in the relevant criterion situation. This key difference must remain to the fore in the writer's mind when designing an experiential rubric.

8. **Consider quality and quantity.**
   The grading of the vocational student's work or performance can be conceptualised in terms of two main axes. The first one is derived from the trade-off between *quality* and *quantity*. Whatever standards of quality apply in the criterion situation should be used to assess the student's work. It is the role of the course to develop the students' knowledge and skills to ensure they can meet the relevant professional standards. By the same token, it is the role of the assessment writer to ensure that the rubric is based on a realistic interpretation of these standards and does not aim instead for an idealised view of what they think professional practice should be. The quantitative aspect of the rubric, meanwhile, also needs to be realistic in relation to the amount of work which can be reasonably expected within the conditions of assessment, especially the time available for completion. Taken together, considerations of quality and quantity will determine how much the student needs to produce, and how well.

9. **Consider scope and depth.**
   The second axis represents the balance between *scope* and *depth*. Just as quality tends to be regarded as more important than quantity as an indicator of competence, the depth of a student's work or performance tends to be valued over and above its scope or its range. Nevertheless, this will not always be the case. Depending on the nature of the assessment task, they may be equally important, or the scope may in fact be more significant and useful in a given professional context, as determined by the criterion situation. A market study, for example, requires in-depth analysis of a specific market. A marketing strategy, on the other hand, should provide a detailed action plan with a range of different tactics and channels to reach potential customers. Similarly, a brainstorming task in IT design may depend more for its overall success in identifying an innovative solution on the quantity of ideas generated than on their inherent quality (Paulus et al., 2011).

10. **Always relate cognition to the workplace context.**
    Finally, it is advisable either to avoid referring to cognitive states or cognitive effort in experiential criteria, or to look for evidence of the student's thinking only in relation to their work / performance in a clearly defined professional context. In general terms, an academic rubric is designed to provide "a description of critical thinking in a discipline and how it might be distinguished from lower levels of thinking" (Orrell, 2023, p.3). An experiential vocational rubric, on the other hand, should be more focused on what students have done in their field of practice, as well as their reflection on what they have done. Adjectives like critical, insightful and perceptive

might not appropriately describe the standards expected in the relevant criterion situation. Conversely, when they are appropriate, their meaning will depend on the professional context on which the assessment task is set. Outside of that context, the assessor's judgement may lack objective credibility.

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