An Industry 4.0 Leadership Competency Framework for the Global Construction Industry

To survive in the current competitive global environment, the construction industry must transition from traditional, labour-intensive practices to advanced, digitised operations. The integration of cyber-physical systems, artificial intelligence, and the Internet of Things seeks to drastically improve the productivity and efficiency of humans, machines, and materials. While digital transformation is an imperative function in modern organisations, its successful execution in the global construction industry remains severely bottlenecked by a critical leadership capability gap. The purpose of this study was to conceptualise and validate a Leadership 4.0 Competency Framework. The study was exploratory in nature, employing a dual-phase qualitative research method. Purposive sampling was used to select peer-reviewed literature for a PRISMA-guided systematic review, followed by primary data gathering from six global construction leadership experts through a semi-structured focus group. Thematic analysis was applied to identify the core competencies required for digital leadership. For technological transformation to have a sustainable managerial impact, leaders must actively bridge micro-level human capabilities with macro-level digital complexities; the findings of this study offer a novel Meso-Level Ecosystem Framework to achieve that.

Keywords: *capability approach, complex adaptive systems, digital transformation, global construction industry, Industry 4.0, leadership competency 4.0*

ONLY FOR REVIEW

Introduction

The onset of Industry 4.0 initiated a profound paradigm shift across global markets, fundamentally altering workplace dynamics and necessitating the rapid retraining of employees to align with technological advancements (Rotatori, Lee & Sleeva, 2021). Professor Klaus Schwab described Industry 4.0 as a time of technological and digital revolution, wherein innovations like robotics, the Internet of Things, and artificial intelligence (AI) are transforming society and eventually becoming part of daily life (Schwab, 2016). The pace of technological developments, the scope of its application, and the enormous influence generated by novel systems set Industry 4.0 apart from previous revolutions.

These sweeping technological changes not only impact broader economic productivity but also radically redefine the role of the leader within the modern enterprise, which now operates across highly complex, interconnected levels (Alade & Windapo, 2021). Leaders now play an important role in developing Industry 4.0 technology skills in employees. This is referred to as reskilling to ensure that the workforce is not left behind by rapid automation (Ivaldi, Scaratti & Fregnan, 2021). To benefit from cutting-edge technologies and approaches, human capabilities, such as hiring and retraining, must be enhanced and actively managed by forward-thinking executives (Barata, 2021). While technical structural properties and material efficiencies remain heavily studied within the sector (Estrada & Lee, 2023),

contemporary market pressures require a corresponding evolution in human resource capital.

For decades, the construction sector has lagged behind manufacturing in productivity gains, largely due to its bespoke, project-based nature and the sheer complexity of site logistics. However, the introduction of Building Information Modelling (BIM), autonomous drones, digital twins, and AI-driven predictive analytics promises to revolutionise project delivery. The shift in leadership dynamics, necessitated by the growing interdependence of human labour and sophisticated cyber-physical systems, has brought about severe operational and psychological obstacles (Tortorella et al., 2022). Workers fear displacement, while middle managers struggle to integrate isolated digital tools into cohesive organisational workflows. Traditional management paradigms, which rely on rigid hierarchical control and transactional exchanges, face severe restrictions in today's fast-paced technological world and prove insufficient for navigating interconnected digital environments (Madanchian et al., 2024).

Ongoing transformations in the global marketplace compel organisations to deploy non-traditional leadership paradigms to navigate complex structural shifts. Because the modern commercial ecosystem is uniquely unstable, conventional leadership methodologies have lost their efficacy and fail to offer reliable strategic pathways (Al Khajeh, 2018). The leadership void becomes increasingly apparent when multi-million-dollar technology investments fail to yield productivity gains because the human workforce rejects the tools or lacks the digital literacy to utilise them effectively. There is a noted leadership vacuum in the technological era that must be resolved by developing new social behaviours and a corporate leadership style that actively deviates from traditional business administration (Yela Aránega, Gonzalo Montesinos & del Val Núñez, 2023).

The specific skills, cognitive attributes, and knowledge needed to develop effective leaders capable of navigating this disruption are referred to as Leadership Competency 4.0 (Fernandez, Noble & Garman, 2021). Maponya and Naidoo (2022) identified the need to close the capability gap among Industry 4.0 leaders. These capability gaps were also confirmed by Oliveira and Saraiva (2023) in their studies of Leadership 4.0.

These findings are recognised as the research problem, namely that Industry 4.0 leaders require new capabilities, must change business processes and utilise different resources to lead their employees to adapt to Industry 4.0 (Behie et al., 2023). In light of the drastic Industry 4.0 technological changes, it was necessary to investigate the connections between Industry 4.0 leadership effectiveness and leadership competencies, including intellectual, managerial, emotional, and social dimensions. Ribeiro, Amaral and Barros (2021) added that construction companies need to focus on effective leadership to maintain profitability and achieve success in the constant changing demands of Industry 4.0.

Consequently, the primary objective of this study was to develop a Leadership 4.0 Competency Framework tailored specifically for the global construction industry. The study specifically considered the distinct competencies and socio-emotional skills that leaders must embrace to encourage innovation, improve operational output, and stay highly competitive in a rapidly changing digital

UNDER PEER REVIEW

ecosystem. By identifying the exact roles, competencies, constraints, and contributing factors inherent to this sector, the study aims to provide a diagnostic and operational tool for construction enterprises seeking to secure a sustainable competitive advantage.

Underpinning Theory and Theoretical Framework

To construct a robust Industry 4.0 Leadership Competency Framework, this study synthesises four complementary theoretical paradigms into a unified operational engine. This synthesis creates a continuous, causal sequence demonstrating how an external leadership role demands a specific internal competency, which encounters systemic constraints, and how overcoming those constraints yields measurable organisational contributing factors. No single theory can adequately capture the multidimensional nature of digital disruption; therefore, a multi-theoretical approach is required to map both the human and economic realities of the modern construction landscape.

The Capability Approach

The normative foundation of this study relies on Amartya Sen's Capability Approach, which dictates that digital transformation must not merely equip the workforce with software but must actively expand human agency and substantive freedoms (Sen, 1999). Development in this era must be understood not as the accumulation of resources, income, or technology per se, but as the expansion of the real opportunities individuals must live lives and have reason to value. Being capable enhances the possibility of achieving personal ideals and professional flourishing.

In the context of Industry 4.0, a leader must function as a capability architect, ensuring that technological adoption enhances worker dignity and professional agency, rather than reducing employees to mere instruments of automated systems. Sen's framework critically distinguishes between 'functionings' (the actual states of being and doing) and 'capabilities' (the real opportunities to achieve those states). Furthermore, Sen (1999) defined agency as the capacity of individuals to act towards change. People must thus be treated as "active participants in development" rather than passive beneficiaries of top-down interventions. For instance, providing a worker with an AI tool is merely a resource; the worker's digital literacy, psychological safety, and leadership support act as the 'conversion factors' that turn that tool into a genuine capability. The study integrates the foundational work of Sen (1999) and Nussbaum (2011) to prioritise human flourishing over mere technological resource accumulation. Ethical governance within Construction 4.0 is operationalised through Naussbaum's concept of practical reason. Thus, the ethical mandate of the modern construction leader is to continuously build these conversion factors, ensuring equitable technological empowerment across the entire project supply chain.

ONLY FOR REVIEW

Dynamic Capabilities Theory (DCT)

To translate these individual capabilities into operational success, leaders must apply them within the highly unpredictable realities of the global construction industry. This operational mechanism is defined by the Dynamic Capabilities Theory (DCT). DCT highlights the organisation's adaptive capacity to sense environmental shifts, seize digital opportunities, and continuously reconfigure internal and external competencies to respond to technological disruption (Teece, Pisano & Shuen, 1997). The construction industry is notoriously vulnerable to external shocks, be they supply chain disruptions, regulatory changes, or rapid technological obsolescence.

Teece (2007) disaggregates dynamic capabilities into three distinct micro-foundational processes: sensing, seizing, and transforming or reconfiguring. Sensing requires the leader to scan the horizon for emerging technologies like 3D printing and advanced robotics, understanding their potential impact on project delivery. Seizing involves committing financial and structural resources to these technologies, making irreversible investments to signal strategic intent. Transforming, or reconfiguring, is the continuous realignment of the firm's tangible and intangible assets to maintain evolutionary fitness. In the construction context, this means restructuring project teams, altering procurement models, and redesigning workflows to fully embed digital tools into the fabric of the organisation.

Complex Adaptive Systems Theory (CAST)

The environment the leader operates within is defined by the Complex Adaptive Systems Theory (CAST). CAST conceptualises the digitised construction landscape as a highly unpredictable, non-linear network of interacting agents where outcomes emerge organically rather than through rigid, top-down control (Uhl-Bien, Marion & McKelvey, 2007). A construction project is not a machine that can be perfectly programmed; it is a living ecosystem of subcontractors, suppliers, engineers, and clients, all interacting simultaneously.

In this paradigm, leadership is reconceptualised as creating the enabling conditions for emergence, innovation, and self-organisation. Leaders cannot force digital adoption through authoritative fiat; they must instead push the organisation to the 'edge of chaos', creating enough disruption to force adaptation while maintaining enough stability to prevent collapse. Emergent order occurs when leaders foster a culture of continuous experimentation, allowing frontline workers to discover the most efficient ways to utilise new digital tools organically (Lichtenstein & Plowman, 2009). CAST thereby explains why traditional, bureaucratic management structures frequently fail during digital transformation: they attempt to impose linear control on a fundamentally non-linear, complex ecosystem.

UNDER PEER REVIEW

Transaction Cost Economics (TCE)

Finally, this complex environment introduces severe digital asset specificity that results in increased transaction costs and governance challenges. Transaction Cost Economics (TCE) is thus employed to define the systemic friction and constraints affecting adoption (Demirkesen & Tezel, 2022). Williamson's framework posits that economic actors structure firms to minimise the costs of planning, adapting, and monitoring task completion. In Construction 4.0, the introduction of highly specialised software, proprietary data environments, and bespoke digital platforms creates immense 'asset specificity'.

Through the TCE lens, the leader acts as an interface coordinator. Because digital contracts are inherently incomplete and cannot account for every technological glitch or data breach, severe governance gaps emerge. This leader must develop strong governance structures, coordinate adaptations through administrative control, manage disagreements based on contractual gaps, and align incentives to reduce opportunistic behaviour and mitigate haggling costs across fragmented supply chains (Williamson, 1996). Without competent leadership to resolve these disputes quickly, the transaction costs of digital adoption will rapidly exceed its operational benefits, leading to project failure and massive financial loss (Williamson, 1985).

Literature Review

The rapid integration of Industry 4.0 technologies has fundamentally altered the expectations and responsibilities of leaders. Traditional management paradigms, such as laissez-faire, transactional, and top-down transformational, are proving incompatible with the interconnectedness of humans and machines (Da Silva et al. 2022). For instance, while transactional leadership works towards making incremental improvements and sustaining levels of performance by offering incentives, it is insufficient to fully unleash the capabilities of engineering staff in Industry 4.0 (Nair Subramanian & Banihashemi, 2024). It relies too heavily on extrinsic rewards and punishments, failing to foster the intrinsic motivation required for creative problem-solving in a digital environment.

Laissez-faire leadership allows passivity and avoidance, making it unsuitable for promoting rapid technological changes (Cardona-Cano, López-Zapata & Velez-Ocampo, 2024). When leaders step back entirely, digital transformation stalls, silos deepen, and the organisation falls prey to competitive obsolescence. Even traditional transformational leadership, with its heavy reliance on top-down charisma, struggles to navigate the highly decentralised, data-driven realities of the modern construction site.

Conversely, Leadership 4.0, often termed digital leadership, is characterised by its speed, cross-hierarchical nature, collaborative attitude, and strong focus on innovation (Guzmán et al. 2020). To succeed, a digital leader must adopt a complete digitalisation mindset, acquire new technical skills, and take on unprecedented ethical responsibilities (Bach & Sulíková, 2021). They must break down

UNDER PEER REVIEW

departmental barriers, encourage interdisciplinary collaboration, and champion a fail-fast culture where experimentation is rewarded.

When AI systems manage site logistics, the leader remains ultimately accountable for the ethical deployment of those algorithms. Furthermore, effective performance in the digital era draws heavily from multiple intelligence domains (Alsalhi, 2020). A modern leader must combine interpersonal abilities, managerial know-how, strategic thinking, emotional intelligence, and administrative efficiency to address the socio-technical gap between human workforces and automated systems (Nair Subramanian & Banihashemi, 2024). They must possess the cognitive agility to understand complex data architecture while maintaining the emotional empathy required to guide a fearful workforce through disruptive change.

Research Methodology

The study was conducted in two specific phases, employing a qualitative research approach where non-numerical data were collected and analysed to gather in-depth, contextual insights. The research design of the study is based on the research onion model, which involves multiple layers of methodology, carefully considered and implemented to produce reliable results (Melnikovas, 2018). The study followed an interpretivist research philosophy (subjectivist ontology and interpretivist epistemology), guiding both the research methods and analyses related to leadership and leadership competencies for the global construction industry. This philosophical stance acknowledges that digital transformation is a socially constructed phenomenon, deeply influenced by human perceptions, organisational culture, and historical context.

Research Design and Sample

Phase 1 utilised the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to explicitly guide the search and screening process, reducing bias and ensuring replicability (Page et al. 2021). Rigorous purposive sampling was used to select peer-reviewed journal articles published globally between 2020 and 2025. Extensive searches were conducted across diverse, high-impact databases, including Science Direct, EBSCOhost, Sabinet, ProQuest, Elsevier, and Scopus. The initial search yielded 250 records. Upon removing duplicate records and applying strict exclusion criteria, including non-English texts and articles lacking specific focus on construction leadership in Industry 4.0, a final 30 full-text articles were selected for the systematic review.

Phase 2 followed an exploratory research design where primary data were systematically collected to empirically validate the proposed conceptual model via expert consensus. A targeted focus group was utilised consisting of six globally recognised Industry 4.0 leadership experts, comprising senior leaders, digital transformation directors, and academic thought leaders currently operating actively within the international construction environment. This elite cohort provided profound insights into the lived realities of digital project delivery.

UNDER PEER REVIEW

Data Collection and Analysis

Document analysis for Phase 1 was conducted using the advanced computer-aided qualitative data analysis software, ATLAS.ti 24. A dual inductive and deductive thematic approach was used to code the text, allowing the researcher to accurately identify categories, map structural themes, and trace the relationships between leadership roles and capabilities. Deductive codes were anchored in established theories like DCT and TCE, while inductive codes were allowed to emerge organically from the texts to capture novel phenomena specific to Industry 4.0.

For Phase 2, a semi-structured, rigorously formulated focus group guide was used to gather primary qualitative data from the identified experts via Microsoft Teams. The data were analysed by interpreting the differences and similarities in the expert feedback using thematic analysis to refine the model's structure and verify its causal logic. Recordings were transcribed verbatim, and the resulting text was subjected to rigorous thematic coding to confirm consensus and isolate divergent viewpoints regarding operational friction and capability building.

Trustworthiness and Ethical Considerations

Trustworthiness across the research lifecycle was ensured through the criteria of credibility, dependability, transferability, and confirmability. Credibility was established by strictly applying the PRISMA method to abstract the study results, mitigating selection bias, and employing prolonged engagement with the texts. Dependability was achieved through methodological triangulation, dense description, and a comprehensive description of the study's protocols and audit trails, allowing independent researchers to trace the exact logic of the thematic categorisations. Transferability was ensured by providing rich contextual detail regarding the global construction sector.

Ethical clearance was formally obtained from the Tshwane University of Technology Research Ethics Committee. All participants provided explicit informed consent, their individual identities were completely anonymised, and data storage protocols adhered strictly to institutional guidelines.

Findings and Discussion

The findings are categorised according to the study's four secondary objectives: determining the role of the leader, identifying specific competencies, exploring constraining factors, and outlining contributing factors. These elements are mapped dynamically through the sensing, seizing, and transforming framework of Dynamic Capabilities Theory. By organising the findings in this manner, the study moves beyond a static checklist of traits and establishes a causal, functional model of leadership action.

ONLY FOR REVIEW

The Role of the Leader within Industry 4.0

The rapid integration of Industry 4.0 technologies has fundamentally altered the expectations and responsibilities of leaders. The secondary data analysis revealed nine prominent themes, mapped onto Teece's Dynamic Capabilities Framework:

- Sensing Roles: Leaders must proactively scan the environment to identify disruptions and opportunities. This involves robust Risk Management (identifying vulnerabilities, assessing social impacts, and anticipating project risks) and maintaining an Openness to Change (recognising when legacy processes must be updated to accommodate advancements). In the construction industry, this means looking beyond traditional civil engineering constraints and exploring how data science, materials innovation, and autonomous robotics can redefine project viability.
- Seizing Roles: Leaders capture value through strategic decision-making. This includes fostering Collaborations and Partnerships (mobilising external expertise across industry and academia), navigating Governance (aligning practices with regulatory frameworks and government support), and driving Strategy Implementation (translating visions into actionable digital roadmaps). Leaders must negotiate complex joint ventures, integrate fragmented supply chains, and secure irreversible budgetary commitments to digital infrastructure.
- Transforming Roles: Leaders fundamentally alter the organisation's culture and structure. They must act as a Change Leader, foster Effective Communication to articulate digital visions and dissolve resistance, actively Motivate Teams to shift traditional mindsets, and continuously Promote Innovation. This is the most demanding role, as it requires dismantling entrenched hierarchies and replacing them with agile, data-driven, and psychologically safe operational ecosystems.

Industry 4.0 Leadership Competencies

To successfully execute these roles, specific internal micro-foundational competencies are required. The analysis identified twelve core competencies that serve as the cognitive, emotional, and ethical engines of digital transformation:

1. Improve Project Efficiency with Forward-Thinking Leadership: Leaders must be forward-thinking, changing how they lead to adjust to fast-shifting technological developments and market demands (Shojaei & Burgess, 2022). They must anticipate supply chain bottlenecks and leverage predictive analytics to prevent schedule overruns.
2. Uphold Ethical Leadership: Leaders must demonstrate ethical intelligence, ensuring the safe, responsible, and ethical use of data and technologies (Marnewick & Marnewick, 2021). This includes protecting worker privacy when deploying IoT wearables and ensuring AI algorithms do not perpetuate systemic biases.

ONLY FOR REVIEW

3. Have Multiple Leadership Intelligences: The ability to adapt knowledge, handle interpersonal relationships judiciously, and utilise knowledge across disciplinary boundaries (Alade & Windapo, 2021).
4. Socio-Emotional Competencies: Emotional intelligence, digital literacy, self-management, and self-awareness are vital to confront challenges with resilience and inspire teams (Rehan, Thorpe & Heravi, 2024).
5. Adapt to Change: The capacity to adapt to new knowledge and implement digital and technological changes proactively, abandoning obsolete practices without hesitation.
6. Leading Virtual Teams: Enhancing communication with virtual teams and building a healthy digital identity, bridging the gap between on-site physical labourers and remote digital engineering hubs.
7. Digital Leadership Transformation: The ability to develop a new strategy, set the implementation plan, and actively guide digital transformation (Nyqvist et al. 2024).
8. Strong Interpersonal Skills: Leading interpersonal relationships to build trust and group synergy for project success.
9. Empower Teams with Motivational Leadership: Creating an environment that encourages continuous improvement and inspires enthusiasm, transforming fear of automation into a drive for upskilling.
10. Technological Risk and Safety Intelligence: The cognitive capacity to oversee self-operating machinery, interpret real-time safety data powered by AI, and mitigate cyber-risks ethically (Sajjad et al. 2023).
11. Ability to Influence and Build an Innovative Environment: Fostering a culture of innovation and supporting staff to experiment with AI-powered automation without fear of punitive repercussions for productive failure.
12. Systemic Intelligence: The ability to integrate technologies, utilise data-driven decision-making, apply analytical thinking, and champion sustainability for Construction 4.0 (Gledson et al. 2023).

Leadership Constraining Factors

The transition to Industry 4.0 faces severe operational friction, which through the lens of Transaction Cost Economics, represent high transaction costs and contractual incompleteness:

1. Risk Perceptions of Leaders: A leader's negative attitude towards risk and lack of knowledge regarding the benefits of digital technology acts as a primary barrier to innovation (Zulu et al. 2024). When executives fear the initial capital expenditure of digital tools, they inadvertently condemn their organisations to long-term obsolescence.
2. Lack of Stakeholder Buy-In: A reluctance to invest in new technologies due to the fragmented nature of the construction industry and tight budgets (Demirkesen & Tezel, 2022). Subcontractors operating on razor-thin margins often refuse to adopt proprietary digital platforms mandated by principal contractors.

ONLY FOR REVIEW

3. Lack of Skilled Staff: A high skills gap in human-machine communication, data analytics, and cybersecurity challenges the adoption of advanced systems (Adepoju & Aigbavboa, 2021).
4. Cyber Threats: The increasing risk of cybersecurity breaches and lack of data protection measures create immense vulnerability (Wang et al. 2024). The digitisation of critical infrastructure data turns construction firms into prime targets for industrial espionage and ransomware.
5. Lack of Digital Literacy: A workforce deficiency in digital skills impedes the operational deployment of cyber-physical systems, leading to massive friction at the human-machine interface.
6. Lack of Industry Standards and Resources: The absence of standards and certification leads to regulatory voids and severe contractual incompleteness (Singh et al. 2023).
7. The Use of Traditional Methods: Entrenched reliance on traditional methods and basic machinery creates systemic resistance to digital disruption. The "we have always done it this way" mindset is a powerful cultural inhibitor.
8. Lack of Data Protection and Privacy: Legal and ethical boundaries of data use remain debated, causing hesitation in adoption and significant legal liability exposure.

Leadership Contributing Factors

To overcome these constraints, specific enabling conditions must be cultivated through deliberate leadership intervention:

1. Integration of Technologies: Embracing Industry 4.0 technologies (AI, robotics, IoT) leads to new improvements in processes and increased efficiency (Bhattacharya & Pant, 2024).
2. An Enabling Environment: Establishing digital technology centres and fostering a dynamic business environment drives leadership success (Ebekozien et al. 2024).
3. Top Management Support: Executive backing is vital for demonstrating commitment, releasing budgets, and driving digital transformation (Zhang et al. 2023). Without vocal and financial backing from the C-suite, middle-management digital initiatives inevitably stall.
4. Risk Management Support: Establishing comprehensive risk management plans and safety protocols to alleviate physical and cyber risks, thereby reducing transaction costs.
5. Positive Relationships: Relationship success factors and effective communication contribute significantly to project delivery and stakeholder management (Rehan et al. 2024).
6. Budget Support: Ensuring projects are completed within budget and aligning policies to secure required funding for technologies.
7. Digital Leadership: Creating a digital-friendly environment where leaders actively address the grand challenges of Construction 4.0, including rapid decarbonisation.

ONLY FOR REVIEW

8. An Innovative Environment: Cultivating a culture of digital innovation that encourages creativity through recognition and rewards (Shojaei & Burgess, 2022).
9. An Implemented Digital Strategy: Establishing a thorough strategic framework to optimise efficiency and align technological innovation with business goals (Chen et al. 2024).
10. Legal Support: Formulating laws and government policies that promote digital transformation and address legal and contractual conflicts proactively.
11. Reskilling/Upskilling: Using Industry 4.0 technologies to upskill the workforce, closing the skills gap and enhancing integrated project delivery (Aghimien et al. 2024).
12. Training and Development: Redesigning educational curricula and providing continuous training for professionals to master technical capabilities, ensuring long-term evolutionary fitness.

Expert Focus Group Validation

The primary data gathered from the six global experts yielded five major thematic validation points, confirming the lived realities of global construction leadership:

- Navigating Operational Frictions and Contractual Issues: Participants confirmed that traditional, rigid procurement models act as severe inhibitors. Technological proficiency must be paired with systemic intelligence to manage operational costs and legacy boundaries. One expert explicitly noted that leaders need a specific competency in "Contractual Agility" to find ways to innovate legally within legacy, rigid contract frameworks, highlighting the precise intersection of TCE and practical site management.
- Strategic and Systemic Intelligence for Communication and Buy-In: Experts reached consensus that cognitive agility is mandatory for managing highly fragmented project ecosystems. Technical knowledge is insufficient without systemic intelligence to secure stakeholder buy-in, particularly through formal contractual relationships like BIM Execution Plans. Complex multi-national projects require leaders who can translate digital mandates across diverse cultural and operational contexts.
- The Emotional and Human Bottleneck of Actual Adoption: Participants validated that the primary barrier is human behaviour and risk perception, rather than software limitations. Emotional intelligence is required to navigate this double bind of recognised value versus adoption anxiety. When field workers fear that automation equates to job loss, only profound socio-emotional leadership can rebuild trust and maintain project momentum.
- Cybersecurity and Ethical Governance: The focus group emphasised that integrating cyber-physical systems elevates data risks directly to life-safety risks. If a smart building's environmental controls are hacked, it transcends

ONLY FOR REVIEW

IT failure and becomes a physical hazard. Ethical governance of AI and standalone cybersecurity capabilities are critical, non-negotiable operational priorities.

- Capacity Building and Investing in the New Ecosystem: Participants concluded that sustainable Industry 4.0 adoption requires significant, long-term investment in organisational capability. You cannot simply hire ready-made digital construction experts; they must be cultivated internally. Without intentional reskilling and upskilling, the digital skills gap will completely stall technological integration and compromise the firm's strategic viability.

The Meso-Level Ecosystem Framework

The empirical findings and expert validations successfully conceptualised the Meso-Level Ecosystem Framework. This framework acts as the critical operational interface where a leader's internal micro-level capabilities (cognitive, emotional, and ethical traits) are deployed to govern and navigate external macro-level organisational demands (the friction of digital transformation). The twelve empirical competencies are synthesised into five overarching theoretical pillars, establishing a holistic paradigm for future industry practice:

- Pillar 1: Digital and Technical Proficiency (Systems Balancing). Grounded in Dynamic Capabilities Theory, leaders must continuously reconfigure technological and human assets to maintain operational equilibrium during rapid digital disruption. Forward-thinking leaders effectively bridge the gap between historical labour-intensive processes and the systemic balancing required for Industry 4.0 efficiency. They serve as the mechanical link between legacy infrastructure and digital innovation.
- Pillar 2: Strategic and Systemic Intelligence (Sensing and Seizing). Anchored in CAST, this pillar is the strategic nervous system. Leaders must apply micro-traits like multiple leadership intelligence and externalise them through macro-strategies, such as executing implemented digital strategies across fragmented supply chains. They must possess cognitive bandwidth to understand how a single data architecture decision impacts downstream procurement, site logistics, and ultimate facility management.
- Pillar 3: Socio-Emotional Excellence (Relational Coordination). Addressing the intensely human-centric challenges of digital disruption, leaders must act as visionary change agents. Relational coordination breaks down psychological resistance and the fear of obsolescence, easing the friction of technological adoption by guiding the human element with emotional intelligence. This pillar recognises that technology fails without human consent and psychological safety.
- Pillar 4: Ethical Governance (Risk and Safety Intelligence). Applying Transaction Cost Economics, leaders must possess digital safety intelligence to design advanced governance mechanisms. This drastic reduction of operational costs and haggling friction ensures ethical boundaries are set for AI usage and

UNDER PEER REVIEW

that data privacy standards are strictly upheld. It demands that leaders protect both the digital rights of their workers and the proprietary data of their clients with uncompromising integrity.

- Pillar 5: Change Adaptability (Capability Building). Rooted fundamentally in the Capability Approach, a firm's competitive advantage relies on continuously building and reconfiguring internal human capabilities. By strategically focusing on human capital, leaders eradicate the structural constraints of skilled staff shortages and digital illiteracy. They transform the construction workforce from manual labourers into digitally empowered knowledge workers, expanding human freedom alongside industrial productivity.

Practical and Managerial Implications

The 5-Pillar framework offers immediate operational utility, serving as an actionable diagnostic instrument for human resource departments to conduct targeted leadership gap analyses and structure effective succession planning. By operationalising this framework, construction firms can actively transition from generic management training to targeted digital capability building, ensuring project directors are equipped to reduce transaction costs and mitigate haggling friction in complex, technology-driven supply chains. Furthermore, executives can utilise this framework to design specific interventions that foster psychological safety and continuous learning across their project networks, actively breaking down the entrenched resistance to automated tools. Organisations can benchmark their current leadership bench against the five pillars, systematically identifying vulnerabilities in their digital transformation strategy.

Limitations

A primary limitation of this study is the absence of its practical operationalisation in a live, real-time mega-project environment; it currently functions as a rigorously validated theoretical and diagnostic guideline. While the theoretical scaffolding is robust, the messy, day-to-day realities of on-site execution may reveal friction points not captured in academic discourse. Furthermore, relying on a systematic literature review means that the findings are limited by the availability of published literature in selected English-language databases, which may slightly restrict their immediate universal generalisability. Finally, while methodologically sound for elite framework validation, the small qualitative sample size of the focus group prevents the statistical modelling of specific trait efficacy across larger population sets.

Recommendations

Future research must prioritise longitudinal, observational studies to test the operational effectiveness of the framework across an extended project lifecycle in

ONLY FOR REVIEW

real-time construction scenarios. Researchers should embed themselves within active project teams to measure how these competencies directly impact critical path delivery and budget adherence. Additionally, empirical research should expand into developing economies to assess how extreme financial constraints, lack of stable power grids, and outdated legacy infrastructure specifically impact the applicability of these leadership competencies. Finally, quantitative structural equation modelling should be explored to assess statistical relationships between emotional intelligence scoring and specific technological adoption rates, moving beyond qualitative consensus into predictive performance analytics.

Conclusions

This research conclusively demonstrates that the successful integration of Industry 4.0 in the global construction industry is fundamentally a leadership imperative rather than a purely technological one. Traditional, mechanistic leadership models are fundamentally incompatible with the complex, adaptive realities of cyber-physical systems. The validated Leadership 4.0 Competency Framework, anchored in the Meso-Level Ecosystem model, provides a definitive, causal blueprint for navigating this volatile digital landscape. By prioritising systemic intelligence, ethical governance, and human-centric capability development, leaders can systematically dismantle entrenched traditional constraints and safeguard the professional agency of the workforce in an increasingly automated age. Ultimately, the framework affirms that technological advancement is unsustainable without an equivalent evolution in leadership capability. The future of construction belongs not to the firms with the most advanced algorithms, but to those guided by leaders possessing the profound socio-emotional and strategic intelligence to weave those algorithms into the human fabric of the enterprise.

References

Adepoju, O. O., and Aigbavboa, C. O. 2021. Assessing knowledge and skills gap for construction 4.0 in a developing economy. *Journal of Public Affairs*, 21(3), e2242.

Aghimien, D., Aigbavboa, C. O., Oke, A. E., and Aliu, J. 2024. Delineating the people-related features required for construction digitalisation. *Construction Innovation*, 24(1), 105–124.

Alade, K., and Windapo, A. O. 2021. Developing effective 4IR leadership framework for construction organisations. *Engineering, Construction and Architectural Management*, 28(5), 1377–1396.

Al Khajeh, E. H. 2018. Impact of leadership styles on organizational performance. Journal of Human Resources Management Research, 2018, 1–10.

Alsalhi, N. R. I. 2020. The representation of multiple intelligences in the science textbook and the extent of awareness of science teachers at the intermediate stage of this theory. *Thinking Skills and Creativity*, 38, 100706.

Bach, C., and Sulíková, R. 2021. Leadership in the context of a New World: Digital leadership and Industry 4.0. *Managing Global Transitions*, 19(3), 209–226.

ONLY FOR REVIEW

Barata, J. 2021. The fourth Industrial Revolution of supply chains: A tertiary study. *Journal of Engineering and Technology Management*, 60, 101624.

Behie, S. W., Pasman, H. J., Khan, F. I., Shell, K., Alarfaj, A., El-Kady, A. H., and Hernandez, M. 2023. Leadership 4.0: The changing landscape of industry management in the smart digital era. *Process Safety and Environmental Protection*, 172, 317–328.

Bhattacharya, S., and Pant, G. 2024. Digital transformation in AECO industry: Impending dilemma in the Indian context. *Journal of Organizational Change Management*, 37(3), 683–699.

Cardona-Cano, R., López-Zapata, E., and Velez-Ocampo, J. 2024. Leadership styles, collaborative integrative behavior and ambidexterity in university research groups. *The Learning Organization*, 31(2), 185–204.

Chen, Z. S., Liang, C. C., Xu, Y. Q., Pedrycz, W., and Skibniewski, M. J. 2024. Dynamic collective opinion generation framework for digital transformation barrier analysis in the construction industry. *Information Fusion*, 103, 102096.

Da Silva, L. B. P., Soltovski, R., Pontes, J., Treinta, F. T., Leitão, P., Mosconi, E., De Resende, L. M. M., and Yoshino, R. T. 2022. Human resources management 4.0: Literature review and trends. *Computers and Industrial Engineering*, 168, 108111.

Demirkesen, S., and Tezel, A. 2022. Investigating major challenges for industry 4.0 adoption among construction companies. *Engineering, Construction and Architectural Management*, 29(3), 1470–1503.

Ebekozien, A., Aigbavboa, C. O., Adekunle, A. S., Aliu, J., and Thwala, W. D. 2024. Training needs of built environment professionals: The role of fourth Industrial Revolution. *Engineering, Construction and Architectural Management*, 31(5), 1957–1975.

Estrada, H., and Lee, L. 2023. Embodied Energy and Carbon Footprint of Concrete Compared to Other Concrete. Athens Journal of Technology & Engineering, 10(2), 115-130.

Fernandez, C. S. P., Noble, C. C., and Garman, L. 2021. A qualitative analysis of maternal and child health public health leadership institute (MCH PHLI) leaders: Assessing the application of leadership skills at the "others" and "wider community" levels of the MCH leadership competencies 4.0. *Maternal and Child Health Journal*, 25(9), 1437–1446.

Gledson, B., Zulu, S. L., Saad, A. M., and Ponton, H. 2023. Digital leadership framework to support firm-level digital transformations for Construction 4.0. *Construction Innovation*, 24(1), 341–364.

Guzmán, V. E., Muschard, B., Gerolamo, M., Kohl, H., and Rozenfeld, H. 2020. Characteristics and skills of leadership in the context of Industry 4.0. *Procedia Manufacturing*, 43, 543–550.

Ivaldi, S., Scaratti, G., and Fregnan, E. 2021. Dwelling within the Fourth Industrial Revolution: Organisational learning for new competences, processes and work cultures. *Journal of Workplace Learning*, 34(1), 1–26.

Lichtenstein, B. B., and Plowman, D. A. 2009. The leadership of emergence: A complex systems leadership theory of emergence at successive organisational levels. *The Leadership Quarterly*, 20(4), 617–630.

Madanchian, M., Taherdoost, H., Vincenti, M., and Mohamed, N. 2024. Transforming leadership practices through artificial intelligence. *Procedia Computer Science*, 235, 2101–2111.

Maponya, C. M., and Naidoo, L. D. 2022. Investigating the leaders' state of readiness in the Department of Telecommunications and Postal Services in South Africa to develop policy for the fourth Industrial Revolution. *Journal of Public Affairs*, 22(4), e2833.

Marnewick, C., and Marnewick, A. 2021. Digital intelligence: A must-have for project managers. *Project Leadership and Society*, 2, 100026.

Melnikovas, A. 2018. Towards an explicit research methodology: Adapting research onion model for futures studies. *Journal of Futures Studies*, 23(2), 29–44.

ONLY FOR REVIEW

Nair Subramanian, S., and Banihashemi, S. 2024. Towards modern leadership styles in the context of the engineering sector. *Project Leadership and Society*, 5, 100133.

Nussbaum, M. C. 2011. Creating capabilities: The human development approach. Belknap Press.

Nyqvist, R., Peltokorpi, A., Lavikka, R., and Ainamo, A. 2024. Building the digital age: Management of digital transformation in the construction industry. *Construction Management and Economics*, 43(4), 262–283.

Oliveira, S. R. M., and Saraiva, M. A. 2023. Leader skills interpreted in the lens of education 4.0. *Procedia Computer Science*, 217, 1296–1304.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., and Moher, D. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71.

Rehan, A., Thorpe, D., and Heravi, A. 2024. A framework for leadership practices and communication in the context of the construction sector. *Project Leadership and Society*, 5, 100142.

Ribeiro, A., Amaral, A., and Barros, T. 2021. Project Manager Competencies in the context of the Industry 4.0. *Procedia Computer Science*, 181, 803–810.

Rotatori, D., Lee, E. J., and Sleeva, S. 2021. The evolution of the workforce during the Fourth Industrial Revolution. *Human Resource Development International*, 24(1), 92–103.

Sajjad, M., Hu, A., Waqar, A., Falqi, I. I., Alsulamy, S. H., Bageis, A. S., and Alshehri, A. M. 2023. Evaluation of the success of Industry 4.0 digitalization practices for sustainable construction management: Chinese construction industry. *Buildings*, 13(7), 1668.

Schwab, K. 2016. *The fourth Industrial Revolution*. World Economic Forum.

Sen, A. 1999. *Development as freedom*. Oxford University Press.

Shojaei, R. S., and Burgess, G. 2022. Non-technical inhibitors: Exploring the adoption of digital innovation in the UK construction industry. *Technological Forecasting and Social Change*, 185, 122036.

Singh, A., Kumar, V., Verma, P., and Kandasamy, J. 2023. Identification and severity assessment of challenges in the adoption of industry 4.0 in Indian construction industry. *Asia Pacific Management Review*, 28(3), 299–315.

Teece, D. J. 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(13), 1319–1350.

Teece, D. J., Pisano, G., and Shuen, A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509–533.

Tortorella, G. L., Cauchick-Miguel, P. A., Li, W., Staines, J., and McFarlane, D. 2022. What does operational excellence mean in the Fourth Industrial Revolution era? International Journal of Production Research, 60(9), 2901-2917.

Uhl-Bien, M., Marion, R., and McKelvey, B. 2007. Complexity leadership theory: Shifting leadership from the industrial age to the knowledge era. *The Leadership Quarterly*, 18(4), 298–318.

Wang, F., Guo, F., Zhang, C., and Schaefer, D. 2024. From Industry 4.0 to Construction 4.0: Barriers to the digital transformation of engineering and construction sectors. *Engineering, Construction and Architectural Management*, 31(1), 136–158.

Williamson, O. E. 1985. *The economic institutions of capitalism: Firms, markets, relational contracting*. Free Press.

Williamson, O. E. 1996. *The mechanisms of governance*. Oxford University Press.

Yela Aránega, A., Gonzalo Montesinos, C., and del Val Núñez, M. T. 2023. Towards an entrepreneurial leadership based on kindness in a digital age. *Journal of Business Research*, 159, 113747.

ONLY FOR REVIEW

Zhang, G., Wang, T., Wang, Y., Zhang, S., Lin, W., Dou, Z., and Du, H. 2023. Study on the influencing factors of digital transformation of construction enterprises from the perspective of dual effects—A hybrid approach based on PLS-SEM and fsQCA. *Sustainability*, 15(7), 6317.

Zulu, S. L., Saad, A. M., Ajayi, S. O., Dulaimi, M., and Unuigbe, M. 2024. Digital leadership enactment in the construction industry: Barriers undermining effective transformation. *Engineering, Construction and Architectural Management*, 31(10), 4062–4078.

ONLY FOR REVIEW