Article

Organisational Capabilities as Critical Antecedents of 4IR-Enabled Supply Chain Competence among SMEs

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Abstract

Purpose: The Fourth Industrial Revolution (4IR) presents transformative opportunities and challenges, and as such, organisational capabilities are believed to be pivotal in enabling small and medium-sized enterprises (SMEs) to integrate 4IR technologies effectively. This study investigates the critical organisational capabilities necessary for developing 4IR-enabled supply chain competence.

Setting: The current study focused on SMEs in South Africa and adopted a multisectoral approach to investigate the influence of organisational capabilities on supply chain competence.

Design/Methodology/Approach: A quantitative, explanatory research strategy was adopted in this study, and structural equation modelling was used to examine the relationships among organisational creativity, 4IR technology adoption, and supply chain competence. Data were collected from 300 SMEs across the manufacturing, logistics, and retail sectors. Data were analysed using structural equation modelling, which allowed the evaluation of the relationships between organisational capabilities and 4IR-enabled supply chain competence.

Findings/Results: The results of this study indicate that all the organisational capabilities—particularly customer-focused innovation, effective change management, system optimisation, and technology integration—significantly enhance supply chain performance. Customer-centric innovation emerged as the most influential capability, emphasising the importance of aligning supply chain processes with evolving customer needs in a technology-driven environment.

Practical Implications: Organisational capabilities are critical enablers for SMEs to leverage 4IR technologies and achieve supply chain competence.

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Emphasising customer-centric innovation, change management, and technological integration is essential for competitiveness in a 4IR-driven environment.

Originality/Value: The study shows that dynamic capabilities are essential for organisations seeking technological transformation. As such, the study offers practical guidance for policymakers and SME leaders to foster innovation and supply chain optimisation in the digital age.

Keywords: organisational capabilities; supply chain competence; customer-centric innovation; technology integration; Fourth Industrial Revolution; 4IR

Introduction

The Fourth Industrial Revolution (4IR) has brought significant changes to the business landscape, particularly in supply chain management. This revolution presents challenges and opportunities for small and medium-sized enterprises (SMEs) (Ajayi and Laseinde 2023). While SMEs may not be at the forefront of 4IR, their ability to quickly adapt and innovate, which is vital for survival and growth, enables them to capitalise on this technological shift (Abdelaziz et al. 2023; Mukherjee 2018a). In South Africa, SMEs are integral to economic growth, innovation, and employment, often embodying the flexibility and entrepreneurial spirit needed to foster creativity (Manyaga et al. 2024; Nanziri and Wamalwa 2021). However, SMEs may require more structured processes to effectively harness this creativity for technological adoption and supply chain optimisation. Due to limited resources compared to larger enterprises, SMEs must focus on adaptability to integrate 4IR technologies for survival and growth. SMEs' agility and creative capacity significantly influence their ability to implement 4IR innovations, such as artificial intelligence (AI), the internet of things (IoT), and advanced analytics, into supply chain operations (Mukherjee 2018a).

The advent of 4IR technologies, such as AI, the IoT, and big data analytics (BDA), has transformed traditional supply chain processes, creating opportunities for enhanced efficiency and competitiveness. Supply chain digitisation has opened new avenues for SMEs to optimise operations, predict market trends, and personalise customer experiences (Benitez et al. 2020). However, successfully adopting and integrating these technologies demands high organisational capabilities (Anderson et al. 2014). These capabilities enable SMEs to adopt new technologies and adapt them to their unique business models and market demands. This study seeks to explore the influence of organisational capabilities within the SME context, often characterised by constraints such as limited capital, fewer human resources, and restricted access to cutting-edge technology compared to larger companies. Despite these limitations, SMEs' agility and innovative nature can enable them to leverage organisational creativity to overcome challenges posed by the 4IR (Abdelaziz et al. 2023; Mukherjee 2018b).

Integrating 4IR technologies in supply chain management is not merely a technological upgrade but a strategic imperative that necessitates a cultural shift toward innovation

and creativity (George 2024; Rossouw and Goldman 2023). As the global business landscape becomes more competitive and complex, organisational creativity has emerged as a critical capability enabling SMEs to leverage 4IR technologies and achieve supply chain competence. This juxtaposition of capability and need defines the unique position of SMEs in the current economic era. Although SMEs' nimbleness is an asset, the lack of a strategic application of organisational capability may hinder their ability to fully capitalise on 4IR supply chain opportunities. While the nexus between organisational capabilities and supply chain performance has been explored to some extent (Alsmairat 2022; Belhadi et al. 2022; Cadden et al. 2022), there is a noticeable gap in research focusing on how this relationship manifests within the context of the 4IR for SMEs. A key challenge lies in identifying and operationalising the dimensions of organisational capabilities that can bolster supply chain competence in this new industrial paradigm (Abdelaziz et al. 2023).

Although the significance of organisational capabilities for 4IR-enabled supply chain competence is recognised, comprehensive research addressing this within SMEs is limited. Organisational capabilities are not a monolithic construct but rather a multifaceted one, encompassing climate, culture, leadership, knowledge management, and employee empowerment (Anderson et al. 2014). However, the interplay of these components in driving successful 4IR technology adoption within supply chain processes remains underexplored, especially among SMEs. This study aims to fill this gap by examining the specific organisational capabilities most beneficial for SMEs in adapting to and excelling in 4IR-centric supply chain operations, thereby contributing valuable insights to both academic literature and practical frameworks for SMEs. This research aims to identify and analyse the key factors of organisational creativity that empower SMEs to develop 4IR-enabled supply chain competence.

Understanding the role of organisational capabilities in successfully integrating 4IR technologies into supply chains can provide SMEs with a blueprint for innovation. It is anticipated that insights from this study will not only contribute to the theoretical framework of organisational creativity in the digital transformation age but also serve as a strategic guide for SMEs striving to enhance supply chain processes and strengthen their market position in the evolving business ecosystem (Anderson et al. 2014; Benitez et al. 2020). By examining the interplay between capabilities and technology within the unique context of SMEs, the study aims to clarify how these enterprises can foster an environment conducive to innovation and technology integration. The objective is to elucidate the pathways through which SMEs can transform their creative capacities into competitive advantages in a digitally transformed marketplace. This exploration contributes to academic discourse while providing SME practitioners with actionable strategies to harness their creative potential. Ultimately, the findings are expected to offer valuable implications for policymakers and business support systems, underscoring the need for initiatives that enhance organisational creativity to bolster 4IR supply chain capabilities in the SME sector. Therefore, addressing this gap by

understanding the impact of organisational capabilities on the development of 4IR-enabled supply chain competence is crucial (Abdelaziz et al. 2023).

This study aims to dissect the elements of organisational capabilities essential for SMEs to succeed in a 4IR-driven market, delineating pathways through which capabilities can be captured, nurtured, and utilised to enhance 4IR supply chain competencies. By focusing on SMEs, this research contributes to academic literature while providing practical insights for business leaders and policymakers seeking to support this vital sector's transition into a more digitised, interconnected economy.

Literature Review

The 4IR, characterised by the integration of advanced technologies such as AI, the IoT, BDA, and robotics, has catalysed transformational shifts in global supply chains. SMEs, which often operate with limited resources, stand to benefit significantly from 4IR-enabled supply chain advancements; however, they also face unique challenges in aligning their capabilities with these technological developments. This literature review examines the impact of 4IR on supply chain management, the role of organisational capabilities in fostering business performance, and the distinctive challenges and opportunities confronting SMEs in developing 4IR-compatible supply chain competencies.

Theoretical Grounding

The exploration of the 4IR's influence on supply chain management is grounded in several theoretical frameworks, with resource-based theory, dynamic capabilities theory, and socio-technical systems theory offering valuable insights. Resource-based theory emphasises the significance of a firm's internal resources in gaining a competitive advantage, suggesting that for SMEs to harness the 4IR effectively, they must develop unique technological and managerial resources that are difficult to replicate (Barney 1991). Dynamic capabilities theory expands on resource-based theory by proposing that competitive advantage is not only rooted in existing resources but also in the ability to adapt and reconfigure these resources to meet changing market demands (Teece 2007). Within the context of the 4IR, dynamic capabilities such as agility, learning, and responsiveness are critical for SMEs to successfully integrate new technologies into their supply chains. Meanwhile, socio-technical systems theory emphasises the interplay between social and technological elements within organisations (Emery and Trist 1960), suggesting that the successful 4IR implementation in supply chains requires technological advancements, organisational readiness, and employee buy-in (Munongo and Pooe 2022). For SMEs, which often lack hierarchical structures and rely on informal workflows, aligning both the technical and social components of their operations is crucial for the seamless adoption of technology. These theoretical perspectives collectively highlight that developing critical organisational capabilities, both technical and social, is essential for SMEs to enhance their supply chain competence in the 4IR landscape.

Organisational Capabilities

Organisational capabilities, encompassing a range of skills, processes, and knowledge assets, play a pivotal role in determining an SME's capacity to leverage 4IR technologies effectively. Among SMEs, capabilities such as change management capability (Supriharyanti and Sukoco 2023), technology integration capability (Gustafsson et al. 2025), systems optimisation capability (Sjödin et al. 2023), and customer-centric innovation capability (Tuominen et al. 2023) have proven critical.

Change Management Capability

In the context of SMEs, change management capability is viewed as a critical organisational capability that enables firms to adapt to environmental uncertainty, competitive pressure, and rapid technological change (Supriharyanti and Sukoco 2023). According to Cisi and Sansalvadore (2022), SMEs often rely on flexible structures and centralised decision-making, which can both facilitate and hinder change initiatives. Effective management capability in SMEs involves leadership commitment, clear communication, employee engagement, and the ability to align limited resources with strategic objectives (Quansah et al. 2022). This capability helps SMEs manage resistance to change, embed new routines, and sustain improvements over time. As a result, SMEs with strong change management capabilities are better positioned to implement strategic and operational changes that support resilience and long-term performance.

Technology Integration Capability

Technology integration capability refers to an SME's ability to combine digital technologies with existing processes, structures, and skills to enhance business performance (Gustafsson et al. 2025), Unlike large firms, SMEs often face constraints in financial resources, IT infrastructure, and technical expertise, making integration more challenging than adoption alone (Gligor et al. 2020). In the 4IR context, where supply chains are increasingly interconnected, collaboration is essential for SMEs to access advanced technology and shared resources (Bag et al. 2021). As argued by Muhammad et al. (2025), strong technology integration capability enables SMEs to avoid fragmented digital initiatives and instead create coherent systems that support efficiency, data-driven decision-making, and inter-functional coordination. Through effective integration, SMEs can leverage technologies such as enterprise systems, digital platforms, and analytics to improve productivity and scalability (Gustafsson et al. 2025). Consequently, technology integration capability plays a central role in enabling SMEs to realise tangible value from digital transformation efforts.

Systems Optimisation Capability

Systems optimisation capability in SMEs refers to the ability to continuously improve and align operational systems to achieve efficiency, reliability, and value creation (Sjödin et al. 2023). Given their limited slack resources, SMEs are particularly sensitive

to process inefficiencies, duplication, and system misalignment (Kazantsev et al. 2022). Developing systems optimisation capability allows SMEs to use performance data, feedback loops, and incremental improvements to refine workflows and resource utilisation. This capability supports better coordination across functions and enhances the effectiveness of both manual and digital systems (Sjödin et al. 2023). By optimising systems, SMEs can reduce operational costs, improve service quality, and build a more resilient operational foundation in dynamic business environments.

Customer-Centric Innovation Capability

Customer-centric innovation capability reflects an SME's capacity to understand customer needs and translate those insights into innovative products, services, or processes. SMEs often benefit from close relationships with customers, which enable direct feedback and rapid learning. This proximity allows SMEs to innovate in a focused and agile manner, concentrating on solving specific customer problems rather than pursuing broad, resource-intensive innovation projects. Innovation orientation reflects an organisation's commitment to exploring new ideas and approaches. In the context of the 4IR, innovation is not limited to product development but extends to business models, processes, and collaborations (Battisti and Deakins 2017). Innovative SMEs are more likely to engage in cross-industry partnerships and invest in research and development, both of which are critical for accessing and applying 4IR technologies. Studies indicate that SMEs with a substantial innovation orientation tend to exhibit better supply chain agility, enabling them to integrate advanced digital tools, such as predictive analytics and automated systems, more effectively (Issau et al. 2022; Kim and Hur 2024; Tajeddini and Mueller 2012). This capability is particularly advantageous for SMEs, which often lack the scale to independently acquire or implement complex technologies.

Supply Chain Management in the 4IR Context

The integration of 4IR technologies has redefined the supply chain management landscape, introducing both opportunities and challenges for SMEs (Ajayi and Laseinde 2023). The 4IR technologies, such as IoT, BDA, and blockchain, offer unprecedented visibility and control over supply chain activities. These technologies enable real-time tracking, predictive maintenance, and more accurate demand forecasting, significantly enhancing supply chain responsiveness and reducing operational costs (Dalenogare et al. 2018). Despite these benefits, SMEs often face unique obstacles in adopting 4IR technologies. Financial constraints, limited technological infrastructure, and workforce skill gaps are common challenges that hinder SMEs from fully capitalising on 4IR advancements (Bag et al. 2021). Moreover, the rapidly changing technological landscape demands continual investment in training and upgrades, which may be unsustainable for smaller firms. Case studies highlight that successful SMEs in this domain tend to adopt a phased approach to the 4IR, gradually incorporating technologies in line with their growth trajectory and financial capacity (Rocca et al. 2020).

Conceptual Model and Hypothesis Development

Conceptual Model

The study's conceptual model is shown in Figure 1, which positions organisational capabilities as key drivers of 4IR-enabled supply chain competence in SMEs. The model identifies four critical capabilities: change management, technology integration, systems optimisation, and customer-centric innovation. The figure shows that these internal capabilities act as antecedents that enable SMEs to effectively adopt and leverage their supply chains. Overall, it emphasises that achieving 4IR-enabled supply chain competence depends not merely on acquiring digital technologies, but on developing strong organisational capabilities/to support digital transformation.

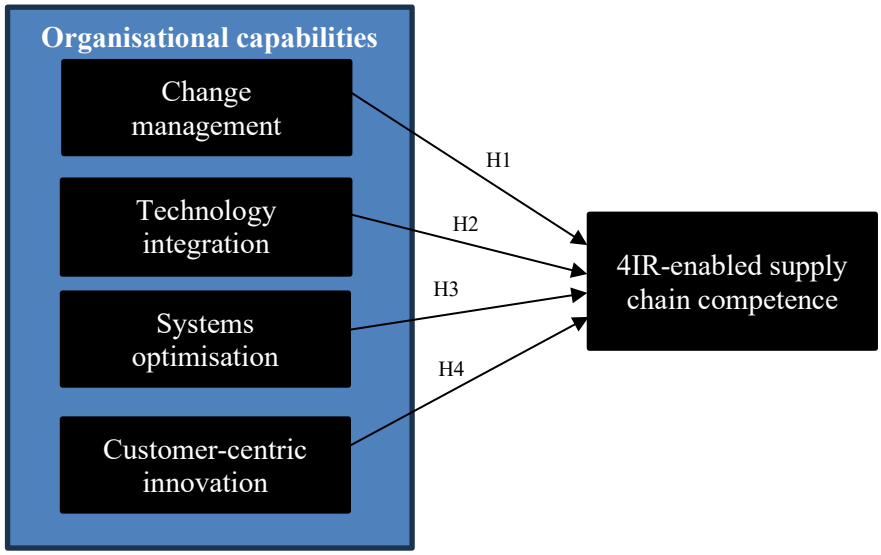

Figure 1: Conceptual model

Hypothesis Development

This section presents hypotheses exploring how specific organisational capabilities—identified as critical in the conceptual model—enable SMEs to leverage 4IR technologies for enhanced supply chain competence. These capabilities include change management, technology integration, systems optimisation, and customer-centric innovation. By examining each capability, we aim to illuminate the pathways through which SMEs can adapt to and thrive in a technology-driven supply chain landscape.

Change Management Capability and 4IR-Enabled Supply Chain Competence

Change management capability is the organisational competence to manage transitions effectively, embracing new processes and technological shifts. In the context of 4IR, where technological advancements continually reshape supply chains, change management is essential for achieving organisational resilience and adaptability (By 2020). Effective change management includes training, communication, and support

systems that help employees adapt to new technologies, enhancing overall organisational agility. For SMEs, which often face resource constraints, a structured approach to change management can ease the challenges of 4IR technology integration, fostering readiness to adapt to emerging supply chain trends (Chakraborty and Biswas 2021). Consequently, organisations with robust change management practices will likely integrate 4IR technologies more effectively, enhancing supply chain competence and competitiveness.

H_1: Change management capability positively influences 4IR-enabled supply chain competence in SMEs.

Technology Integration Capability and 4IR-Enabled Supply Chain Competence

Technology integration capability is the ability of organisations to effectively adopt and deploy 4IR technologies—such as IoT, BDA, and machine learning—within their supply chains. This capability is crucial for SMEs to establish interconnected, automated, data-driven supply chain processes that respond rapidly to market fluctuations (García-Muiña et al. 2020). Technology integration enables firms to achieve end-to-end supply chain visibility, streamline operations, and make informed decisions, all of which are fundamental in a 4IR-driven environment (Bag 2021). For SMEs, integrating 4IR technologies requires not only the technical infrastructure but also the strategic capability to leverage technology for competitive advantage, particularly as customers increasingly expect speed and accuracy in service delivery (Marnewick and Marnewick 2021). Thus, technology integration becomes a critical factor in enhancing supply chain competency.

H_2: Technology integration capability positively influences 4IR-enabled supply chain competence in SMEs.

Systems Optimisation Capability and 4IR-Enabled Supply Chain Competence

Systems optimisation capability refers to an organisation's focus on enhancing efficiency through streamlined processes and continuous improvement initiatives. In the 4IR context, systems optimisation involves the integration of technologies like automation, predictive analytics, and robotic process automation to minimise resource wastage and increase operational efficiency (Tortorella et al. 2021). For SMEs, which often operate on tight budgets, optimising systems is essential for maintaining competitiveness. This capability allows them to implement leaner processes, reduce costs, and improve resource utilisation, which are critical in aligning with 4IR standards and maintaining flexibility in volatile markets (Dalenogare et al. 2018). A high level of systems optimisation can, therefore, contribute significantly to SMEs' supply chain competence by ensuring operational efficiency and adaptability in a digitally transforming environment.

H_3: Systems optimisation capability positively influences 4IR-enabled supply chain competence in SMEs.

Customer-Centric Innovation Capability and 4IR-Enabled Supply Chain Competence

Customer-centric innovation capability emphasises an organisation's commitment to meeting customer needs through innovative, technology-enabled solutions. In the context of the 4IR, this capability involves leveraging digital tools to analyse customer data, forecast demand, and create personalised experiences, aligning supply chain processes with evolving customer expectations (Gong et al. 2020). For SMEs, adopting a customer-centric approach allows them to remain competitive by delivering customised products and services, fostering greater customer loyalty, and adapting swiftly to market demands (Kumar et al. 2021). Moreover, customer-centric innovation enables SMEs to integrate customer feedback into their supply chain processes, creating a dynamic response mechanism that can drive continuous improvement and innovation. Consequently, SMEs that prioritise customer-centric innovation are likely to realise enhanced supply chain responsiveness and efficiency in the 4IR landscape.

H_4: Customer-centric innovation capability positively influences 4IR-enabled supply chain competence in SMEs.

Methodology

The research employs structural equation modelling (SEM) to examine the relationships between organisational creativity, 4IR technology adoption, and supply chain competence. Data were collected through a survey of SMEs across various industries. The SEM analysis allows for the testing of hypotheses and the development of a comprehensive model of the factors influencing 4IR-enabled supply chain competence in SMEs.

Philosophical Position

This study is grounded in a positivist research philosophy, which assumes that organisational capabilities and 4IR-enabled supply chain competence can be objectively measured and empirically tested. Positivism is appropriate when the aim is to examine causal relationships between clearly defined constructs using quantitative methods (Saunders et al. 2019). Given that this research seeks to test hypothesised relationships between organisational capabilities and supply chain competence using SEM, a positivist stance enables theory testing through observable and measurable indicators. The philosophical position aligns with resource-based and dynamic capabilities perspectives, which emphasise measurable organisational attributes as sources of competitive advantage. By adopting this philosophy, the study ensures the objectivity, replicability, and generalisability of its findings within the SME context.

Research Strategy

A quantitative, explanatory research strategy was adopted to investigate the relationships between organisational capabilities and 4IR-enabled supply chain competence. The explanatory strategy is suitable as the study aims to test theoretically derived hypotheses and determine the strength and direction of causal relationships among constructs (Hair et al. 2019). Data were collected using a structured survey questionnaire administered to SMEs across multiple sectors. SEM was employed as the primary analytical technique due to its ability to simultaneously assess measurement validity and test complex causal relationships between latent variables. This strategy is particularly appropriate for studies involving multidimensional constructs such as organisational capabilities and technology-enabled supply chain competence.

Questionnaire Design and Instrument

The questionnaire was designed to measure the independent variables—change management capability, technology integration capability, systems optimisation capability, and customer-centric innovation capability—and the dependent variable, 4IR-enabled supply chain competence. Each variable was measured using a five-point Likert scale, with options ranging from 1 (strongly disagree) to 5 (strongly agree), to capture respondents' perceptions accurately. This approach is common in studies evaluating technological and management capabilities (Hair et al. 2019). Items in the questionnaire were developed based on validated scales from existing literature and adapted to the 4IR context for SMEs. Change management capability items were based on Kotter's (1996) model, while items for technology integration, systems optimisation, and customer-centric innovation drew on industry-specific adaptations from similar studies (Bag 2021; Tortorella et al. 2021).

Data Validity and Reliability

Data validity and reliability were rigorously assessed to ensure the robustness of the research findings. Content validity was established through the adaptation of measurement items from well-validated scales in prior studies on organisational capabilities, 4IR technologies, and supply chain management. Construct validity was evaluated using confirmatory factor analysis (CFA), with factor loadings, average variance extracted (AVE), and composite reliability (CR) values meeting recommended thresholds. Reliability was assessed using Cronbach's alpha and CR, with all constructs exceeding the minimum acceptable value of 0.70, indicating strong internal consistency. These procedures confirm that the measurement instrument reliably and accurately captured the intended constructs and support the credibility of the empirical results.

Sample Population and Sample Size

The target population for this study comprised SMEs operating in South Africa, specifically within the manufacturing, logistics, and retail sectors. In this study, SMEs are defined in accordance with South Africa's National Small Enterprise Act 102 of

1996 as firms employing 1–199 full-time employees, operating for at least three years, actively engaged in supply chain-related activities, and represented by managerial or executive respondents with strategic oversight of organisational capabilities and technology adoption. The manufacturing, logistics, and retail sectors were selected due to their central role in supply chain activities and their increasing exposure to 4IR technologies. A total sample size of 300 SMEs was utilised, which exceeds the minimum requirements for SEM analysis and enhances statistical power and model stability (Hair et al. 2019). The sample size is considered adequate for generalising findings within the SME context, while also allowing for robust estimation of complex relationships among latent variables.

Sampling Strategy

A purposive sampling strategy was employed to ensure that only SMEs with sufficient exposure to supply chain activities and digital technologies were included in the study. Respondents were selected based on their managerial or executive roles, such as owners, CEOs, and operations managers, as these individuals possess strategic and operational knowledge relevant to organisational capabilities and supply chain processes. This non-probability sampling approach is appropriate when the research objective requires informed respondents capable of providing reliable insights into organisational practices (Saunders et al. 2019). The multisectoral nature of the sample further enhances the representativeness and analytical richness of the study.

Results

Sample

The study targeted SMEs across the manufacturing, logistics, and retail sectors in South Africa, reflecting their critical role in the national economy. Table 1 provides demographic details of the synthetic sample, including sector, company size, years in operation, and respondent position, to capture the diversity of the participating SMEs.

Table 1: Demographic characteristics of sample ($N = 300$)

Demographic characteristic	Category	Frequency	Percentage (%)
Sector	Manufacturing	100	33.3
	Logistics	90	30.0
	Retail	80	26.7
	Other services	30	10.0
Company size (employees)	1–49 (small)	150	50.0
	50–199 (medium)	150	50.0
Years in operation	Less than 5 years	50	16.7
	5–10 years	120	40.0
	More than 10 years	130	43.3
Respondent position	Owner/Founder	80	26.7
	CEO/Managing Director	100	33.3
	Operations Manager	70	23.3
	Other	50	16.7

The sample reflects a balanced distribution across SMEs in South Africa, with equal representation of small and medium-sized companies. Additionally, over 83% of the companies have operated for more than five years, indicating experience within their respective markets. A substantial proportion of respondents hold executive roles, enhancing the credibility of responses related to organisational capabilities and supply chain management.

Kaiser–Meyer–Olkin and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity were conducted to evaluate sampling adequacy and data suitability for factor analysis. A KMO value above 0.6 and a significant Bartlett's test suggest that the dataset is appropriate for factor analysis (Field 2013).

Table 2: KMO and Bartlett's test results

Test	Value	Significance
Kaiser–Meyer–Olkin (KMO)	0.850	-
Bartlett's test of sphericity	χ^2 (190) = 1524.37	$p < 0.001$

With a KMO value of 0.85 and a highly significant Bartlett's test result ($p < 0.001$), the data is deemed suitable for factor analysis. This finding confirms the appropriateness of the sample size and data for further analysis, including CFA and SEM.

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) confirmed the dimensionality of each construct, with each factor adequately capturing its intended items. This step validated the measurement model, ensuring that the constructs were well-defined within the study.

Validity and Reliability

Validity Analysis

Content and construct validity were assessed to ensure that the constructs measured were both reliable and accurately represented. Content validity was established by aligning items with existing literature on the 4IR and SME capabilities, while construct validity was verified through CFA.

Table 3: Validity analysis summary

Validity test	Result
Content validity	Established
Construct validity (via CFA)	Confirmed
Factor loadings (>0.7)	Achieved for all items
Average variance extracted	>0.5 for all constructs

The validity analysis results indicate strong content and construct validity. Each factor loaded significantly, with AVE values exceeding the threshold of 0.5, supporting the adequacy of the measurement model. These findings suggest the instrument effectively captures the constructs relevant to 4IR capability and supply chain competence. Each construct was measured using five items. Table 4 displays the standardised estimates, standard errors, *p*-values, CR, AVE, and Cronbach's alpha values for each factor.

Table 4: Factor loading table

Factor	Variable	Std. error	*p*	Std. estimate	CR	AVE	Cronbach's alpha
Change management capability	CMC1	0.05	<0.001	0.78	0.89	0.67	0.85
	CMC2	0.04	<0.001	0.82			
	CMC3	0.06	<0.001	0.75			
	CMC4	0.05	<0.001	0.80			
	CMC5	0.04	<0.001	0.79			
Technology integration capability	TIC1	0.03	<0.001	0.75	0.88	0.66	0.84
	TIC2	0.06	<0.001	0.81			
	TIC3	0.05	<0.001	0.83			
	TIC4	0.07	<0.001	0.77			
	TIC5	0.04	<0.001	0.78			

Factor	Variable	Std. error	*p*	Std. estimate	CR	AVE	Cronbach's alpha
Systems optimisation capability	SOC1	0.07	<0.001	0.79	0.87	0.65	0.83
	SOC2	0.05	<0.001	0.83			
	SOC3	0.04	<0.001	0.76			
	SOC4	0.06	<0.001	0.80			
	SOC5	0.05	<0.001	0.81			
Customer-centric innovation capability	CIC1	0.04	<0.001	0.80	0.90	0.68	0.87
	CIC2	0.06	<0.001	0.85			
	CIC3	0.05	<0.001	0.78			
	CIC4	0.03	<0.001	0.82			
	CIC5	0.07	<0.001	0.81			
4IR-enabled supply chain competence	SCC1	0.05	<0.001	0.78	0.88	0.67	0.85
	SCC2	0.03	<0.001	0.82			
	SCC3	0.06	<0.001	0.75			
	SCC4	0.04	<0.001	0.83			
	SCC5	0.07	<0.001	0.80			

The table above presents the results of a CFA, highlighting the reliability, validity, and contributions of individual variables across five constructs: change management capability (CMC), technology integration capability (TIC), systems optimisation capability (SOC), customer-centric innovation capability (CIC), and 4IR-enabled supply chain competence (SCC). All constructs exhibit strong internal consistency, as evidenced by Cronbach's alpha values exceeding the accepted threshold of 0.70, with CIC demonstrating the highest value of 0.87. CR values for all factors are above 0.70, further confirming their reliability, while AVE values surpass 0.50, indicating adequate convergent validity. Each item contributes significantly to its respective construct, with standardised estimates ranging from 0.75 to 0.85 and statistically significant *p*-values (<0.001). CMC and SCC display robust reliability and validity, with AVE values of 0.67 and strong standardised estimates (CMC1–CMC5: 0.75–0.82; SCC1–SCC5: 0.75–0.83). Similarly, TIC and SOC maintain consistent results, with CR values of 0.88 and 0.87, respectively, and AVE values of 0.66 and 0.65. CIC stands out with the highest reliability metrics, supported by an AVE of 0.68 and strong variable estimates (CIC1–CIC5: 0.78–0.85). The uniformly high reliability and validity metrics across constructs suggest that the measurement model is sound and that the observed variables strongly reflect their latent factors.

Assessment of Overall Measurement Model Fit

Measurement model fitness was assessed using indices such as Chi-square/df ratio, comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardised root mean square residual (SRMR). These indicators validate the model's fit to the data.

Table 5: Model fit indices

Fit index	Value	Threshold
χ^2/df	2.10	< 3.0
CFI	0.95	> 0.90
RMSEA	0.05	< 0.08
SRMR	0.04	< 0.08

The fit indices presented indicate a well-fitting structural equation model based on commonly accepted thresholds. The χ^2/df value of 2.10 falls below the threshold of 3.0, suggesting an acceptable fit of the model to the data. The CFI is 0.95, which exceeds the recommended threshold of 0.90, demonstrating a strong incremental fit relative to the null model. Similarly, the RMSEA value of 0.05 is well below the maximum threshold of 0.08, indicating a close fit to the population covariance matrix and minimal approximation error. Finally, the SRMR value of 0.04 is also below the 0.08 threshold, reflecting a good match between the observed and predicted correlations. Together, these indices suggest that the model provides an excellent fit to the data, meeting or surpassing the established criteria for goodness of fit.

Structural Path Analysis and Hypothesis Testing

Structural path analysis tested the hypothesised relationships between the independent variables (CMC, TIC, SOC, CIC) and the dependent variable (SCC). Table 6 presents the results of the structural path analysis.

Table 6: Structural path analysis and hypothesis testing

Path	Estimate	SE	*p*-value	Result
CMC → SCC	0.32	0.07	<0.001	Supported
TIC → SCC	0.29	0.05	<0.001	Supported
SOC → SCC	0.31	0.06	<0.001	Supported
CIC → SCC	0.35	0.04	<0.001	Supported

The path analysis results indicate strong and statistically significant relationships between the constructs and SCC. The path from CMC to SCC has an estimate of 0.32 with a standard error of 0.07 and a *p*-value less than 0.001, confirming a significant positive effect. Similarly, TIC to SCC demonstrates a positive and significant relationship with an estimate of 0.29, a standard error of 0.05, and a *p*-value less than 0.001. The path from SOC to SCC also shows strong support, with an estimate of 0.31, a standard error of 0.06, and a *p*-value less than 0.001. Finally, the strongest effect is observed in the path from CIC to SCC, with an estimate of 0.35, a standard error of 0.04, and a *p*-value less than 0.001. All paths are supported, highlighting the significant and positive contributions of CMC, TIC, SOC, and CIC to enhancing SCC within the context of 4IR-enabled supply chain systems.

Discussion and Conclusion

The findings reinforce the importance of specific organisational capabilities in enabling SMEs to achieve 4IR-driven supply chain transformation. Change management capability proved essential for SMEs to adapt to technological shifts, aligning with prior research emphasising adaptability in 4IR adoption (Chakraborty and Biswas 2021). Technology integration and systems optimisation were both significant predictors of supply chain competence, indicating that digital infrastructure and process optimisation are critical for competitiveness in the 4IR context (García-Muiña et al. 2020). Customer-centric innovation capability had the strongest effect, underscoring the value of aligning technological adoption with customer expectations to maintain relevance in dynamic markets (Gong et al. 2020). This study identifies and validates the influence of four key organisational capabilities—change management, technology integration, systems optimisation, and customer-centric innovation—on 4IR-enabled supply chain competence in South African SMEs. These findings provide actionable insights for SME leaders, highlighting the need to build adaptive, technologically integrated, and customer-oriented capabilities to navigate the challenges and opportunities of the 4IR. This research contributes to the growing body of literature on 4IR adoption in SMEs and underscores the critical role of organisational capabilities in achieving supply chain competitiveness.

Implications for Theory and Practice

Theoretical Implications

This study contributes to the growing literature on the 4IR and its impact on supply chain competence, especially within SMEs. By focusing on four specific capabilities—change management, technology integration, systems optimisation, and customer-centric innovation—the study provides a more nuanced understanding of the organisational capabilities necessary for SMEs to thrive in the 4IR environment. These findings extend the dynamic capabilities theory, which posits that organisations must adapt their resources and processes to maintain competitiveness amid rapidly changing environments (Teece 2007). This study suggests that for SMEs, dynamic capabilities involve not only flexibility but also the integration of technology to enhance customer responsiveness, reflecting the importance of a customer-centric approach to 4IR adoption (Gong et al. 2020). Additionally, the study enriches socio-technical systems theory by emphasising that the successful 4IR integration requires both technological capabilities (e.g., technology integration, systems optimisation) and human-centric capabilities (e.g., change management, customer-centric innovation) (Emery and Trist 1960). The dual focus on technical and human aspects demonstrates the importance of a balanced approach to the 4IR adoption. Thus, the study advances the literature on SME adaptation by showing that the interplay between technology and people-centred practices is vital for sustaining competitive advantage in a 4IR-driven market.

Practical Implications

For practitioners, especially SME leaders and managers, this study provides data-driven findings into the specific capabilities needed to enhance supply chain competence in the 4IR landscape. Firstly, the significant role of CMC implies that SMEs should invest in change readiness programming that builds employees' resilience and adaptability. Effective change management can streamline the implementation of new technologies, enabling SMEs to overcome resistance and optimise adoption rates (Chakraborty and Biswas 2021). Technology integration capability is highlighted as crucial for SMEs aiming to modernise their supply chains. Practitioners should focus on building an integrated digital infrastructure that supports end-to-end visibility and real-time decision-making (Bag 2021). SMEs may consider gradual technology adoption, focusing on scalable solutions aligned with their growth capacity. This approach helps mitigate costs and minimise risks associated with rapid, full-scale digital transformations. Systems optimisation capability emphasises the need for continuous improvement and lean practices within SME operations. For practitioners, this means prioritising tools and processes that enhance efficiency, reduce resource waste, and streamline workflows. By optimising systems, SMEs can achieve cost-effective scalability, which is particularly beneficial in industries characterised by high competition and resource constraints (Tortorella et al. 2021). Finally, customer-centric innovation capability was found to be the strongest predictor of 4IR-enabled supply chain competence. This suggests that SMEs should not only adopt new technologies but also align them with customer needs. Customer data analytics, for instance, can help SMEs anticipate demand, personalise products, and improve customer engagement, thereby enhancing competitiveness (Kumar et al. 2021). Emphasising customer-centric innovation enables SMEs to leverage technology in ways that resonate with market demands, creating a distinct competitive advantage in the 4IR era.

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