EVOLVING PARADIGMS IN OPERATIONS MANAGEMENT: A SYSTEMATIC REVIEW OF INDUSTRY 4.0 TO 5.0 TRANSITIONS IN SOUTH AFRICAN SUPPLY CHAINS

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ABSTRACT

***Background**: The rapid advancement from Industry 4.0 to Industry 5.0 is reshaping global operational landscapes, introducing a new era where technology, strategy, and sustainability intersect. This evolution is particularly significant in South Africa, where supply chains are a critical component of the economic framework and are increasingly influenced by technological innovations, demanding a comprehensive understanding of their implications.*
***Purpose of the Study**: This study aims to systematically review the existing literature to explore the evolving paradigms in operations management as businesses transition from Industry 4.0 to Industry 5.0, focusing on the South African supply chain context. The primary objective is to ascertain how this transition impacts operational practices, decision-making processes, and overall supply chain efficiency.*
Design/Methodology/Approach: Adopting a systematic literature review methodology, the study analyses 13 peer-reviewed articles, employing thematic analysis to identify, synthesise, and interpret the significant themes emerging from the literature. The PRISMA framework guided the selection and review process, ensuring a rigorous and replicable research approach.
***Results/Findings**: The findings reveal that the transition from Industry 4.0 to Industry 5.0 in South African supply chains is driving a significant shift toward more integrated, intelligent, and sustainable operations. Key themes identified include the pivotal role of advanced technologies like AI and IoT, the increasing importance of data-driven decision-making, and the integration of sustainability and innovation in operational frameworks.*
***Recommendations**: Future research should focus on empirical studies to validate the theoretical insights and explore the practical implications of Industry 5.0 technologies. For industry practitioners, embracing a strategic approach to technology adoption, fostering a culture of innovation, and prioritizing sustainability are recommended to leverage the opportunities presented by this transition.*
***Managerial Implication**: Managers and industry leaders must navigate the complexities of this new industrial era by developing competencies in emerging technologies, adopting resilient and adaptive operational strategies, and championing sustainability. Policymakers should facilitate this transition through supportive regulations, fostering innovation ecosystems, and ensuring the workforce is equipped with the requisite skills for a future-oriented industry.*

Keywords: Industry 4.0 To 5.0 Transition; Operations Management; South African Supply Chains; Technological Innovation; Sustainable Practices.

1. INTRODUCTION

A detailed study of the emergence of Industry 4.0 and its impact on worldwide business activities has been conducted (Mohiuddin, Azad, Ahmed, Ed-Dafali & Reza, 2022). Research on the shift from Industry 4.0 to 5.0 is of great importance, particularly when considering supply chains in South Africa. The transition to

Industry 5.0 represents notable progress in operational frameworks, namely in the field of supply chain management.

In the setting of South Africa, where there are significant changes in health patterns and an increasing burden of diseases, especially renal diseases (George, Brandenburg, Fabian, Crowther, Agongo, Alberts, Ali, Asiki, Boua, Gómez-Olivé, Mashinya, Micklesfield, Mohamed, Mukomana, Norris, Oduro, Soo, Sorgho, Wade, Naicker & Ramsay, 2019), it is crucial to have effective and sophisticated supply chain management techniques. The development of short food supply chain theory and practice, together with its associated sustainability considerations, highlights the significance of adjusting to new paradigms in operations management (Lankauskienė, Vidickienė & Gedminaitė-Raudonė, 2022). Furthermore, the utilisation of system dynamics models for the purpose of dynamic capacity planning in closed-loop supply chains Vlachos, Georgiadis and Iakovou (2007) and Statsenko, Gorod and Ireland (2018) emphasise the importance of adopting innovative approaches and frameworks to improve the effectiveness and sustainability of supply chain management.

Strategic closed-loop supply chain architectures are crucial in the context of moving towards a circular economy (Chizaryfard, Lapko & Trucco, 2023). Comprehending the structural composition and development of supply chain alliance networks is essential for adjusting to shifting industry dynamics (Park, Bellamy & Basole, 2018). Furthermore, the study conducted by Mubiena and Ma'ruf (2018) emphasises the significance of incorporating sustainability concepts into operational plans through the creation of assessment models for sustainable supply chain management.

1.1 Industry 4.0 and 5.0

Contextualising Industry 4.0 and 5.0 within the global and South African context involves understanding the integration of cyber-physical systems, the Internet of Things (IoT), and artificial intelligence in manufacturing processes, revolutionising operational practices worldwide. The shift from Industry 4.0 to 5.0 in South African supply chains is a multifaceted undertaking that necessitates a profound comprehension of the technological, administrative, and human dimensions of major industrial transformations. Machado, Winroth and Ribeiro da Silva (2019) both highlight the imperative of sustainable manufacturing and the pivotal role of management in facilitating this change. Sommer (2015) and Jamwal, Agrawal, Sharma and Giallanza (2021) emphasise the difficulties and possibilities that small and medium-sized firms (SMEs) face throughout this shift, specifically regarding their preparedness and capacity. Alvarez-Aros and Bernal-Torres (2021) and Sony and Naik (2020) offer a comprehensive analysis that explores the significance of technological competitiveness and the incorporation of socio-technical systems theory in the process of transition. Winkelhaus and Grosse (2019) provides detailed analysis on the logistics consequences of this change, whereas Liboni, Cezarino, Jabbour, Oliveira and Stefanelli (2019) focuses on the human resource management aspects. These studies emphasise the importance of taking a comprehensive strategy to the transition, which considers the technological, managerial, and human aspects of Industry 4.0 and 5.0.

1.2 Operations management and supply chains

The study of the transition in operations management and supply chains, specifically in the context of Industry 4.0 to 5.0, is an important and crucial field of research. The integration of circular economy and Industry 4.0 is utilised for sustainable supply chain management (Lu, Zhao & Liu, 2024). Augmented reality and virtual reality are employed in operations and supply chain management (Akbari, Ha & Kok, 2022). Supply chain activities in the energy production sector, specifically in renewables, are managed (Hassanin & Knez, 2022). This transition also includes the transformation of supply chain management from traditional methods to current SCM 4.0, with an emphasis on sustainable SCM and SCM 4.0 (Hariharasudan, Kot & Sangeetha, 2021). Additionally, it encompasses the examination of the connection between entrepreneurial orientation and supply chain management (Cortes, Lee, Cortes & Liñan, 2021), the assessment and organisation of behavioural operations and supply chain management literature (Fahimnia, Pournader, Siemsen, Bendoly & Wang, 2019),

and the evaluation of the concept of digitisation and the fourth industrial revolution in supply chain management (Ali, 2022). Finally, it encompasses the examination of the correlation between leadership and the supply chain of the company (Prabhu & Srivastava, 2022). These studies emphasise the significance of investigating the shift in operations management and supply chains, specifically in the context of Industry 4.0 to 5.0. They offer useful insights for future research in this field.

2. BACKGROUND AND LITERATURE REVIEW

2.1 Key technologies, and principles

Industry 4.0 represents the fourth industrial revolution characterized by the integration of cyber-physical systems, the Internet of Things (IoT), and artificial intelligence into manufacturing processes (Ryalat, ElMoaqet & AlFaouri, 2023). Industry 4.0 relies on several crucial technologies, such as big data, cloud computing, IoT, and cyber-physical systems, to improve industrial performance (Xu & Duan, 2019). Industry 4.0 concepts prioritise flexibility, automation, and data-driven decision-making to enhance operational processes and foster innovation (Czvetkó, Kummer, Ruppert & Abonyi, 2022). Conversely, Industry 5.0 represents a progression towards increased collaboration between humans and machines, as well as decentralised decision-making. It highlights the significance of combining human abilities with new technologies (Dwivedi, Hughes, Ismagilova, Aarts, Coombs, Crick, Duan, Dwivedi, Edwards & Eirug, 2021). The objective of transitioning to Industry 5.0 is to establish production and operations management systems that are more flexible and responsive, with a focus on prioritising human-centered methods (Mourtzis, Angelopoulos & Panopoulos, 2022). The transition to Industry 5.0 signifies a comprehensive perspective on operations, considering not just technology progress but also the socio-economic consequences of industrial activities.

Industry 4.0 and 5.0 have brought about significant changes in manufacturing processes on a global scale, resulting in improved efficiency, productivity, and innovation (Rüßmann, Lorenz, Gerbert, Waldner, Justus, Engel & Harnisch, 2015). These innovations have transformed conventional operational paradigms, resulting in the development of increasingly linked and intelligent systems that enhance competitiveness and sustainability across numerous industries (Preuveneers & Ilie-Zudor, 2017). The adoption of Industry 4.0 and the impending transition to Industry 5.0 have significant implications for businesses worldwide, necessitating a strategic approach to leverage emerging technologies effectively.

Implementing Industry 4.0 technologies in supply chains is essential in the South African environment to improve operational efficiency and competitiveness (Bag, Telukdarie, Pretorius & Gupta, 2021). Utilising important technologies like IoT and big data analytics, South African businesses can enhance their supply chain processes and adjust to evolving market dynamics (Bag, Wood, Xu, Dhamija & Kayikci, 2020). The adoption of Industry 5.0 in South Africa offers a chance to promote innovation, collaboration, and sustainable practices in the local manufacturing and supply chain industries (Zizic, Mladineo, Gjeldum & Celent, 2022).

2.2 Historical evolution and current trends

Historical evolution and current trends in operations management have been influenced by various factors. The historical injustices and health policy transformations in South Africa since 2009 have shaped the healthcare landscape, emphasizing the need for efficient and innovative operational practices (Mayosi, Lawn, Niekerk, Bradshaw, Karim & Coovadia, 2012). Understanding the historical context of South Africa is crucial for comprehending the current challenges and opportunities in operations management within the country.

Moreover, the relevance debate in South African and American psychology highlights the importance of historical perspectives in shaping contemporary discussions and decision-making processes (Sher & Long, 2012). By historicising debates and trends, a deeper understanding of the evolution of operational paradigms can be achieved, leading to more informed and contextually relevant strategies.

Globalised values and postcolonial responses have also played a significant role in shaping operational practices, emphasizing the need to renegotiate ethical frameworks and align them with current historical,

political, and cultural contexts (Wasserman, 2006). This suggests that operations management strategies must be adaptive and responsive to the evolving socio-political landscape to remain effective and sustainable.

In the context of Industry 4.0 and 5.0 transitions, the evolutionary history of diseases like leprosy and the genetic mutations associated with meningococcal disease in South Africa underscore the importance of integrating advancements in healthcare with operational efficiency (Franco-Jarava, Comas, Orren, Hernández-González & Colobran, 2017; Blevins, Crane, Lum, Furuta, Fox & Stone, 2020) These historical insights inform current trends in operations management, highlighting the interconnectedness of healthcare, technology, and operational strategies.

Furthermore, the scientific credibility of industrial and organizational psychology and the role of environmental entrepreneurship as an innovation catalyst demonstrate the diverse influences on contemporary operational practices ((Zyl & Junker, 2019; Diale, Kanakana-Katumba & Maladzhi, 2021). The examination of historical trajectories and current research trends, a comprehensive understanding of the evolution of operations management in South Africa can be achieved, paving the way for strategic and sustainable transitions from Industry 4.0 to 5.0 in supply chains.

2.3 The impact of these industrial transitions

The impact of industrial transitions, particularly from Industry 4.0 to 5.0, on operations management has been a subject of growing interest. Studies Burgess, Jeske, Rasool, Ahmad, Kydd and Mlilo (2021) have explored the impact of complex interventions in challenging contexts like South Africa, shedding light on the feasibility and effectiveness of interventions in healthcare settings. Understanding the implications of such interventions is crucial for optimising operational strategies in South African supply chains.

In addition, Eyaa, Sridharan and Ryan (2021) have conducted an in-depth analysis of the elements that drive opportunistic behaviour in Uganda's manufacturing sector. Their research provides insight on the contextual factors that influence opportunistic behaviours within specific industry sectors. This study enhances comprehension of operational issues and opportunities in African environments by examining opportunistic engagement across industries. The findings can be applied to South African supply chains. Ratshidi, Grobbelaar and Botha (2020) They have classified the elements that affect community health workers from a socio-technical systems viewpoint. They highlight the significance of technological solutions in improving the effectiveness and recognition of these workers in healthcare systems. These findings are helpful for optimising operational methods and utilising technology in South African supply chains to enhance healthcare delivery. Moreover, Urban and Govender (2012) have presented empirical data about environmental management practices, emphasising the growing focus of organisations on environmental effects and the global need for enhanced environmental performance. Comprehending these patterns is crucial for harmonising operational strategies in South African supply chains with sustainability objectives and environmental excellence.

3. METHODOLOGY

3.1 PRISMA method

The objective of conducting a systematic review was to provide a comprehensive and structured synthesis of existing literature on the transitions from Industry 4.0 to 5.0 within South African supply chains. This systematic review aims to identify, analyse, and evaluate the current state of knowledge, trends, challenges, and opportunities related to this transition, thereby contributing to a deeper understanding of the evolution of operations management paradigms in the South African context.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology has been chosen for this review due to its established reputation as a robust and widely recognised framework for conducting systematic reviews (Page, McKenzie, Bossuyt, Boutron, Hoffmann, Mulrow, Shamseer, Tetzlaff, Akl & Brennan, 2021). PRISMA provides a structured approach that ensures transparency, reproducibility, and methodological rigour throughout the review process (Page et al., 2021). By adhering to the PRISMA guidelines,

the systematic review in this study was followed by a standardised methodology for literature search, selection, data extraction, and synthesis, enhancing the credibility and reliability of the review findings (Polojärvi, Palmer & Dunford, 2023).

Moreover, the use of PRISMA methodology facilitates clear and comprehensive reporting of the review process, enabling readers to assess the quality and validity of the review methodology and results. The systematic application of PRISMA guidelines ensures that the review is conducted in a systematic and transparent manner, minimising bias and enhancing the overall quality of the research. By employing PRISMA, this systematic review aims to provide a rigorous and structured analysis of the transitions from Industry 4.0 to 5.0 in South African supply chains, contributing valuable insights to the field of operations management.

The PRISMA framework comprises three stages: identification, screening, and inclusion. The identification stage determines the keywords for the literature search and the sources to be searched. The screening stage outlines the criteria for selecting relevant literature from the initial search results. The inclusion stage describes the final literature included in the study after excluding irrelevant sources. See Figure 1 below.

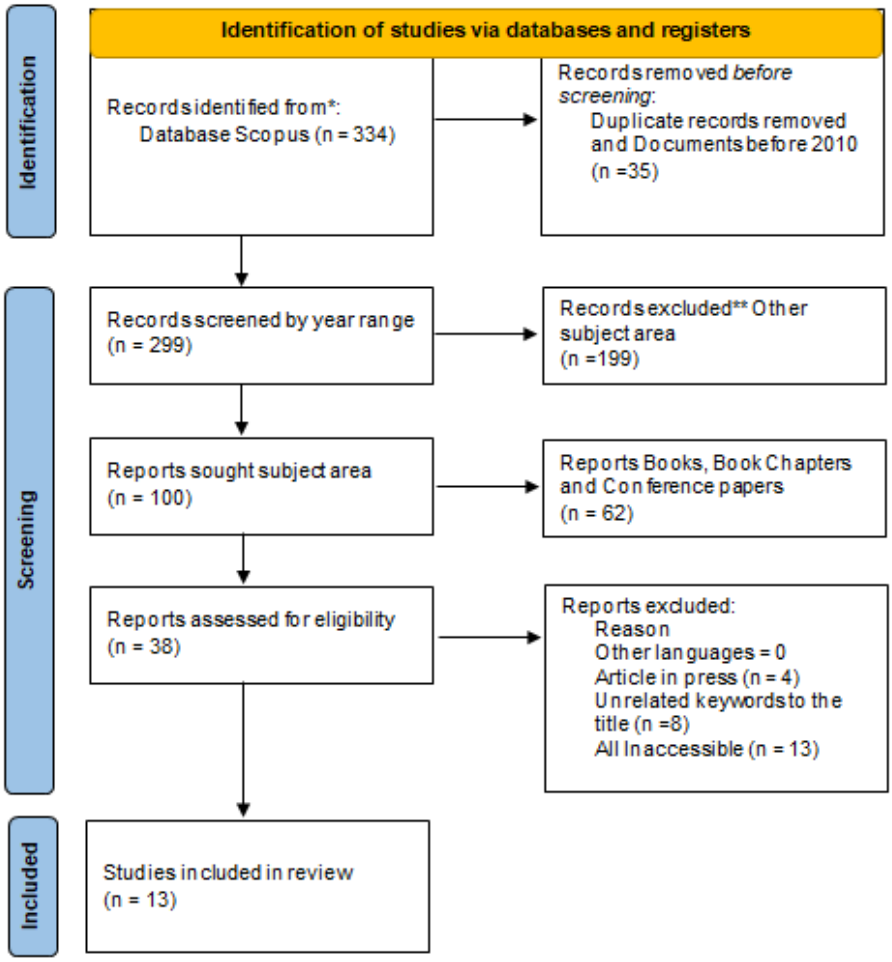

FIGURE 1
PRISMA FRAMEWORK

Source: Rethlefsen, Kirtley, Waffenschmidt, Ayala, Moher, Page and Koffel (2021)

We utilised the Scopus database for the literature search in accordance with the PRISMA methodology during the identification step. The researchers selected the Scopus database due to their institutional access.

Keywords and their combinations considered during the identification stage for the search included Industry 4.0 OR Fourth Industrial Revolution AND Industry 5.0 OR Fifth Industrial Revolution AND operations management OR supply chain management OR supply chain OR logistics AND transition OR transformation OR impact OR effect AND African supply chain. A first search was performed using all keywords to gain an overview of publications using these terms. 334 items were acquired in all. During the identification stage, the output must be reviewed before proceeding to the screening stage. We deleted publications published before 2010 because of a significant increase in studies on Industry 4.0 and Industry 5.0 in 2016. Industry 4.0 and Industry 5.0 are AI technologies that gained recognition in 2020 (Rachakatla & Garrepalli, 2024). Articles published in 2024 were excluded from the preliminary screening as we focused solely on full-year data. Figure 2 shows the document by year on Industry 4.0 and Industry 5.0 from 2010 to 2023.

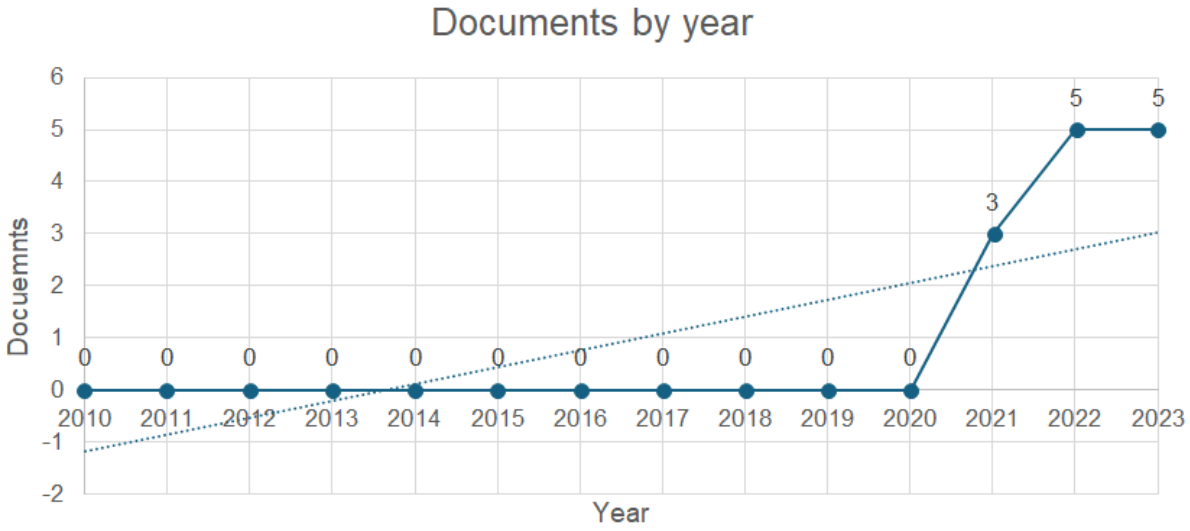

FIGURE 2

DOCUMENTS BY YEAR

Figure 2 above shows the chronological distribution of relevant documents in this systematic literature review. The graph is a line chart showing the number of documents every year from 2010 to 2023. The horizontal axis shows the years being studied, and the vertical axis measures the number of documents published each year.

The data starts in 2010, showing no documents, which remains consistent until 2020. The paucity of publications indicates a scarcity of academic attention or existing study on the shift from Industry 4.0 to Industry 5.0 in South African supply chains at this time. In 2021, the chart shows a significant increase in research effort with the emergence of one document. This initial appearance is crucial because it signifies the beginning of scholarly discussion on the subject within the defined geographic and thematic boundaries.

The trend of document publication sharply rises, as shown by the line's trajectory. In 2021, the graph shows an increase from one document to three, and this growth continues until 2022 with five papers. The data for 2023 shows five documents, indicating a plateau in the number of publications for that year, which is the maximum level seen over the period studied.

The data indicates a growing scholarly focus on the effects of Industry 4.0 to 5.0 transitions on operations management in South African supply chains, especially starting in 2020. The increase in document production from 2020 to 2022 may indicate a greater awareness of the importance of this change, which may be influenced

by technological progress, economic needs, or changes in strategic goals in the area. The stabilisation in document counts in 2023, although occurring early in the year, may suggest a consolidation phase in the research effort or a natural fluctuation in academic production.

3.2 Criteria for inclusion and exclusion of studies

Table 1 in the Systematic Review outlines the methodical procedure used to select and reject documents in order to determine the effects of transitioning from Industry 4.0 to Industry 5.0 on operations management in South African supply chains. An initial search produced 334 documents before filtering for inclusion. Out of these, 299 documents pertained to the selected time frame of 2010 to 2023. An in-depth investigation of a certain topic area reduced the number of documents to 100 in the domains of Business, Management, and Accounting. After refining based on document type, 38 articles and reviews were selected, all published in English. At the publication stage, 34 documents were finalised, and 26 documents had keywords linked to the title. Only open-access documents were included, resulting in 13 open-access documents. Thirteen reports were ultimately included in the study.

The exclusion criteria were thoroughly implemented as well. No documents were excluded during the initial search process. 35 documents were eliminated due to being published before 2010. 199 documents were excluded from consideration due to not being aligned with the stated fields within the scope of the topic area. Furthermore, 62 documents were eliminated due to being books, book chapters, or conference papers. No papers were rejected based on language criteria, as all documents in the first search were in English. Four papers were omitted from publication due to being articles in the press, while eight were deleted for having terms irrelevant to the title. Thirteen documents were removed due to inaccessibility, as it was one of the criteria. A total of 321 reports were omitted from the analysis. The meticulous selection process ensures that the documents chosen for the study are highly relevant and contribute to understanding the changing paradigms in operations management as Industry 4.0 shifts to Industry 5.0 in the South African supply chain context.

Table 1: Inclusion and exclusion of studies

Category	**Included**	**Number of documents included**
Initial search	Documents before screening	334
Year Range	2010-2023	299
Subject area	Business, Management and Accounting	100
Document type	Articles and Reviews	38
Language	English	38
Publication stage	Final	34
Keywords	Related keywords to the title	26
Open access	All open access	13
Final Included reports	Included for the analysis	13
Category	**Excluded**	**Number of documents excluded**
Initial search	Documents before screening	0
Year Range	Documents before 2010	35
Subject area	Other subject area	199

Document type	Books, Book Chapters and Conference papers	62
Language	Other languages	0
Publication stage	Article in press	4
Keywords	unrelated keywords to the title	8
Open access	All Inaccessible	13
Final excluded reports	Not included	321

Source: Authors

Search strategy, data sources, and selection process

3.3 Searching keywords

Industry 4.0 OR Fourth Industrial Revolution AND Industry 5.0 OR Fifth Industrial Revolution AND operations management OR supply chain management OR supply chain OR logistics AND transition OR transformation OR impact OR effect AND African supply chain Search string query.

industry 4.0 OR fourth AND industrial AND revolution AND industry 5.0 OR fifth AND industrial AND revolution AND operations AND management OR supply AND chain AND management OR supply AND chain OR logistics AND transition OR transformation OR impact OR effect AND african AND supply AND chain AND PUBYEAR > 2009 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , " BUSI")) AND (LIMIT-TO (DOCTYPE , " ar") OR LIMIT-TO (DOCTYPE , " re")) AND (LIMIT-TO (LANGUAGE , " English")) AND (LIMIT-TO (PUBSTAGE , " final")) AND (LIMIT-TO (EXACTKEYWORD , " Industry 4.0") OR LIMIT-TO (EXACTKEYWORD , " Big Data") OR LIMIT-TO (EXACTKEYWORD , " Artificial Intelligence") OR LIMIT-TO (EXACTKEYWORD , " Supply Chain Management") OR LIMIT-TO (EXACTKEYWORD , " Systematic Review") OR LIMIT-TO (EXACTKEYWORD , " Quality 4.0") OR LIMIT-TO (EXACTKEYWORD , " Technological Innovation") OR LIMIT-TO (EXACTKEYWORD , " Supply Chains") OR LIMIT-TO (EXACTKEYWORD , " Logistics") OR LIMIT-TO (EXACTKEYWORD , " Internet Of Things") OR LIMIT-TO (EXACTKEYWORD , " Innovation") OR LIMIT-TO (EXACTKEYWORD , " Digitization") OR LIMIT-TO (EXACTKEYWORD , " Digitalization") OR LIMIT-TO (EXACTKEYWORD , " Digital Transformation") OR LIMIT-TO (EXACTKEYWORD , " Developing Countries") OR LIMIT-TO (EXACTKEYWORD , " Big Data Analytics") OR LIMIT-TO (EXACTKEYWORD , " Africa") OR LIMIT-TO (EXACTKEYWORD , " Information Technology") OR LIMIT-TO (EXACTKEYWORD , " Industrial Technology") OR LIMIT-TO (EXACTKEYWORD , " Industrial Management") OR LIMIT-TO (EXACTKEYWORD , " Industrial Research") OR LIMIT-TO (EXACTKEYWORD , " Information Management") OR LIMIT-TO (EXACTKEYWORD , " Information And Communication Technology") OR LIMIT-TO (EXACTKEYWORD , " Green Supply Chain") OR LIMIT-TO (EXACTKEYWORD , " Generative AI") OR LIMIT-TO (EXACTKEYWORD , " Fourth Industrial Revolution") OR LIMIT-TO (EXACTKEYWORD , " Digitalisation") OR LIMIT-TO (EXACTKEYWORD , " Digital Technology") OR LIMIT-TO (EXACTKEYWORD , " Digital Supply Chain") OR LIMIT-TO (EXACTKEYWORD , " Data-driven Supply Chain Quality Management Practices (DDSCQMPs)") OR LIMIT-TO (EXACTKEYWORD , " Data-driven Supply Chain Quality Management Practice") OR LIMIT-TO (EXACTKEYWORD , " Blockchain Technology") OR LIMIT-TO (EXACTKEYWORD , " ChatGPT") OR LIMIT-TO (EXACTKEYWORD , " Challenges") OR LIMIT-TO (EXACTKEYWORD , " Business") OR LIMIT-TO (EXACTKEYWORD , " Blockchain") OR LIMIT-TO (EXACTKEYWORD , " Big Data Analytic") OR LIMIT-TO (EXACTKEYWORD , " Artificial Intelligence Technologies") OR LIMIT-TO (EXACTKEYWORD , " Firm Digitalization")) AND (LIMIT-TO (OA , " all"))

TITLE-ABS-KEY((" Industry 4.0" OR " Fourth Industrial Revolution" OR " 4IR") AND (" Industry 5.0" OR " Fifth Industrial Revolution" OR " 5IR") AND (" operations management" OR " supply chain management" OR " supply chain" OR " logistics") AND (" transition" OR " transformation" OR " impact" OR " effect") AND (" South Africa" OR " African supply chain"))

According to PRISMA guidelines, screening is the second stage when the final query mentioned above is utilised. The query specifies papers on Industry 4.0 and Industry 5.0 in the context of South Africa, published between 2010 and 2023. Only open-access articles and reviews written in English were included. The query resulted in 13 articles and reviews.

The inclusion stage was conducted after the screening stage. At this point, the 13 articles retrieved from the search query were evaluated. These 13 articles were transferred to a CSV file format for additional refinement and examination in Microsoft Excel. We searched for duplicate articles and articles in the " In Press" publication stage in Excel. No papers were deleted because they did not match the deletion criteria. Analysed the total amount of citations in Excel. Table 2 displays the citation analysis details for each of the 13 articles and reviews.

In the context of this systematic literature review, Table 2 provides a scholarly examination of the impact of the cited works in the field. The table lists a selection of academic articles, along with their authors, publication year, title, journal, and the frequency with which they have been cited.

Examining the " cited by" data uncovers the range of impact that these articles hold in the academic world. Bag, Gupta, Kumar and Sivarajah (2021) study, " An integrated artificial intelligence framework for knowledge creation and B2B marketing rational decision making for improving firm performance," published in Industrial Marketing Management, has received 125 citations, placing it at the top. The high number of citations shows that the work has received great recognition and has likely impacted further study in the fields of artificial intelligence, knowledge production, and B2B marketing in the context of Industry 4.0.

The article " Industry 4.0 in Healthcare: A systematic review" by Ahsan and Siddique (2022) in the International Journal of Information Management Data Insights has received 35 citations. This indicates a strong scholarly involvement with the subject of Industry 4.0 in the healthcare industry. Rejeb, Rejeb, Abdollahi, Al-Turjman and Treiblmaier (2022)'s bibliometric analysis on the Internet of Things and agriculture, published on the Internet of Things (Netherlands) in 2022, has garnered significant attention with 28 citations, highlighting the relevance of this research field.

Midgley and Lindhult (2021) provide a systems perspective on systemic innovation in Systems Research and Behavioural Science. Their work has been cited 23 times, showing the importance of systemic approaches in studying innovation during Industry 4.0 transitions.

Skalli, Charkaoui, Cherrafi, Garza-Reyes, Antony and Shokri (2023) published a study on combining Industry 4.0 and Lean Six Sigma in manufacturing. The research has received 15 citations and was featured in the Quality Management Journal, indicating a rising interest in operational strategies during the fourth industrial revolution.

Aghimien, Ikuabe, Aigbavboa, Oke and Shirinda (2021), Javaid, Haleem, Singh, Suman and Khan (2022), and Ardito (2023) have contributed to the discourse with 8, 6, and 5 citations respectively. Their work focuses on topics including big data analytics in construction, blockchain technology applications, and the impact of firm digitalization on sustainable innovation performance.

Alhalalmeh (2022) has investigated the impact of supply chain 4.0 technologies on Uncertain Supply Chain Management. The research has received 2 citations, indicating that this field is gaining academic recognition as an emerging area of study.

Table 2. Article citations analysis

Authors	Year	Title	Journal	Cited by
Bag S.; Gupta S.; Kumar A.; Sivarajah U.	2021	An integrated artificial intelligence framework for knowledge creation and B2B marketing rational decision making for improving firm performance	Industrial Marketing Management	125
Ahsan M.M.; Siddique Z.	2022	Industry 4.0 in Healthcare: A systematic review	International Journal of Information Management Data Insights	35
Rejeb A.; Rejeb K.; Abdollahi A.; Al-Turjman F.; Treiblmaier H.	2022	The Interplay between the Internet of Things and agriculture: A bibliometric analysis and research agenda	Internet of Things (Netherlands)	28
Midgley G.; Lindhult E.	2021	A systems perspective on systemic innovation	Systems Research and Behavioral Science	23
Skalli D.; Charkaoui A.; Cherrafi A.; Garza-Reyes J.A.; Antony J.; Shokri A.	2023	Industry 4.0 and Lean Six Sigma integration in manufacturing: A literature review, an integrated framework and proposed research perspectives	Quality Management Journal	15

Aghimien D.O.; Ikuabe M.; Aigbavboa C.; Oke A.; Shirinda W.	2021	Unravelling the factors influencing construction organisations' intention to adopt big data analytics in South Africa	Construction Economics and Building	8
Javaid M.; Haleem A.; Singh R.P.; Suman R.; Khan S.	2022	A review of Blockchain Technology applications for financial services	BenchCouncil Transactions on Benchmarks, Standards and Evaluations	6
Ardito L.	2023	The influence of firm digitalization on sustainable innovation performance and the moderating role of corporate sustainability practices: An empirical investigation	Business Strategy and the Environment	5
Alhalalmeh M.I.	2022	The impact of supply chain 4.0 technologies on its strategic outcomes	Uncertain Supply Chain Management	2
Mtotywa M.M.; Dube T.	2023	State of Quality 4.0 in the South African chrome mining industry: Gap analysis and priority areas for improvement	Cogent Business and Management	0
Doanh D.C.; Dufek Z.; Ejdys J.;	2023	Generative AI in the manufacturing	Engineering Management in	0

Ginevičius R.; Korzynski P.; Mazurek G.; Paliszkiewicz J.; Wach K.; Ziemba E.		process: theoretical considerations	Production and Services	
Adenigbo A.J.; Mageto J.; Luke R.	2023	Adopting Technological Innovations in the Air Cargo Logistics Industry in South Africa	Logistics	0
Alrasheedi N.S.; Sammon D.; McCarthy S.	2022	Understanding the characteristics of workforce transformation in a digital transformation context	Journal of Decision Systems	0

Source: Authors

It is advisable to exclude research that has not been cited. Due to the limited number of articles meeting our search criteria, papers that had not been cited were retained. The next section presents the outcomes of the thematic analysis of the 13 articles, including the identified themes and the final themes' review. The salient themes from the 13 articles meeting the inclusion criteria for the systematic literature review were reported following these steps.

4. RESULTS

4.1 *Thematic analysis using atlas-ti for data synthesis*

Thirteen articles were evaluated using the thematic analysis method. The study utilised the thematic analysis process outlined by Soratto, Pires and Friese (2020), which consists of three main phases for qualitative thematic data analysis: pre-analysis, material exploration, and interpretation. The salient themes from the 13 articles meeting the inclusion criteria for the systematic literature review were reported following these processes. See Table 3 below.

Table 3. Thematic analysis phases

Phases of thematic analysis	**Steps in ATLAS.ti**
First phase: Pre-analysis.	Creating the project. Adding documents. Grouping documents into document groups.

	Writing first memos on the overall project aim including research questions.
Second phase: Material exploration.	Reading the data, selecting data segments and creating quotations. Creating and applying codes. Writing memos and comments. Grouping codes and memos
Third phase: Interpretation.	Exploring the coded data using various analysis tools. Linking quotations, codes, and memos on the conceptual level. Continuing memo writing. Generating network views. Extracting reports.

Source: Soratto et al. (2020)

4.2 Pre-analysis Phase

This initial phase involves setting up the project structure in Atlas.ti, which includes creating the project, adding documents, categorising these documents into groups, and drafting initial memos that encapsulate the primary aim of our research, including our research questions. In the context of our study, this phase would entail.

- Creating the Project: Establish a dedicated project in Atlas.ti, naming it in alignment with our study's focus.
- Adding Documents: Import the selected articles that discuss the impact of Industry 4.0 to 5.0 transitions, particularly in the context of South African supply chains.
- Grouping Documents: Organize these documents into categories such as technological impacts, operational changes, human resource implications, etc.
- Writing Memos: Draft initial thoughts on how the transition might influence operations management based on a preliminary review of the literature

4.3 Material exploration phase

This phase is about delving into the data, which involves reading the documents, selecting relevant data segments, creating quotations, coding the data, and continuously writing memos to capture insights. Specific steps for our study would include:

- Reading the Data: Engage with the content of the articles, understanding the nuanced perspectives on the Industry 4.0 to 5.0 transition.
- Selecting Data Segments and Creating Quotations: Identify and highlight segments that directly relate to operations management impacts.
- Creating and Applying Codes: Develop a coding scheme that captures various themes like technological innovation, workforce transformation, operational efficiency, etc., and apply these codes to the relevant segments.
- Writing Memos and Comments: Document insights, hypotheses, and observations that emerge during the coding process.

4.4 Interpretation phase

The final phase focuses on synthesising the coded data to draw meaningful insights. This involves linking quotations, codes, and memos conceptually, continuing the memo-writing process to refine the analysis, generating network views to visualise the relationships between themes, and extracting reports for detailed examination. In our context, this would entail:

- Exploring Coded Data: Use Atlas.ti's analysis tools to examine the coded segments, identifying patterns, trends, and emerging themes related to the Industry 4.0 to 5.0 transition.
- Linking Quotations, Codes, and Memos: Develop a coherent narrative that connects the empirical findings with the theoretical frameworks related to operations management.
- Generating Network Views: Visualise the interconnections between different themes to understand the holistic impact of the industry transition.

Extracting Reports: Compile the coded data and analysis into comprehensive reports that succinctly present the findings and their implications for operations management in the context of South African supply chains.

Adhering to this structured methodology ensures a thorough and systematic exploration of how the transition from Industry 4.0 to Industry 5.0 is reshaping operations management in South African supply chains, thereby providing insightful conclusions and recommendations for practitioners and scholars in the field.

4.5 Presentation of the findings from the systematic review

Figure 3 displays a word cloud that visually shows how often keywords appear in the literature analysed in this systematic literature review. The visualisation emphasises the key terms crucial to studying the impact of transitioning from Industry 4.0 to Industry 5.0 on operations management in South African supply chains. The word cloud prominently features terms like " industry," " innovation," " supply chain," " technologies," " data," and " digitalisation" in larger fonts, suggesting their significance in the research. The literature primarily focuses on the technological developments and innovative techniques of Industry 4.0 and Industry 5.0, especially in relation to their use in supply chain management. The interest in specific technologies such as " blockchain," " artificial intelligence," and " big data" is shown in the significant representation of these terms, indicating their role in driving the progress of operations management. These terms highlight the importance of these areas in the industry's digital transformation. Additional significant terminology related to the methodological parts of the systematic review are " research," " study," " review," and " literature." The phrases emphasise the scholarly and academic aspects of the discussion and the use of scholarly methods to combine information in the topic. Words such as " financial," " cargo," " construction," " marketing," and " quality" are smaller but still evident. These words may indicate certain sectors or parts of operations management that are impacted by the shift to advanced industrial stages. The analysis of the word cloud reveals a complex research landscape in South Africa, highlighting the intricate relationship between technology, innovation, and management concepts. The focus on digital and emerging technologies like as blockchain and artificial intelligence demonstrates a forward-thinking approach, recognising their potential to transform operations management and the supply chain. The word cloud succinctly represents the main themes of the current literature, providing a visual overview of the research topics most relevant to the transition from Industry 4.0 to 5.0 in South African supply chains. It is a valuable tool for pinpointing important areas of attention and any deficiencies in the literature, which can guide future research endeavours.

FIGURE 3
WORD CLOUD

Source: Authors

Figure 4 in this study displays a line graph showing grounded codes generated from Atlas-ti, a qualitative data analysis software. The graph shows how often certain codes from the analysed texts appear, reflecting the recurring themes and concepts in the literature about the effects of transitioning from Industry 4.0 to Industry 5.0 on operations management in South African supply chains. The graph's horizontal axis lists the recognised codes, which symbolise important concepts or themes found in the research material. The codes encompass terms like " Artificial Intelligence," " B2B Marketing," " Big Data Analytics," " Blockchain Technology," " Digital Transformation," " Generative AI," " Industry 4.0," " Information and Communication Technologies," " IoT," " Machine Learning," " Systems Perspective," and " Technological Innovations." The vertical axis measures the frequency with which a specific code has been cited in the data, indicating the level of groundedness of each code in the text. The graph employs a numerical scale to represent the frequency of each code's occurrence. The graph analysis shows that some codes have a higher level of groundedness, suggesting they are more prevalent in the literature.

The term " Digital Transformation" is the most frequently mentioned code, appearing three times, highlighting its important role and significance in discussions about the shift between industrial paradigms. Digital transformation is a crucial idea in the development of operations management methods in South African supply chains. Additional codes including " Artificial Intelligence," " B2B Marketing," and " Industry 4.0" have a frequency of two, suggesting they are also of notable interest, though significantly less than digital transformation. The codes represent the fundamental elements of Industry 4.0 and the sectors that could undergo significant changes with the advent of Industry 5.0.

On the other hand, terms such as " Big Data Analytics," " Blockchain Technology," " Generative AI," " Information and Communication Technologies," " IoT," " Machine Learning," " Systems Perspective," and " Technological Innovations" all have a groundedness score of one. While these concepts are clearly found in the literature, they are less common, indicating that they may reflect more specialist or emerging areas of interest within the broader themes of industry change and operations management. The line graph effectively illustrates

the relative importance given to different topics in academic study, offering insights into the thematic organisation of the field. The emphasis on codes concerning technological progress and their incorporation into operational plans reflects the literature's interest in comprehending the effects of new technologies on South African supply networks during their evolution.

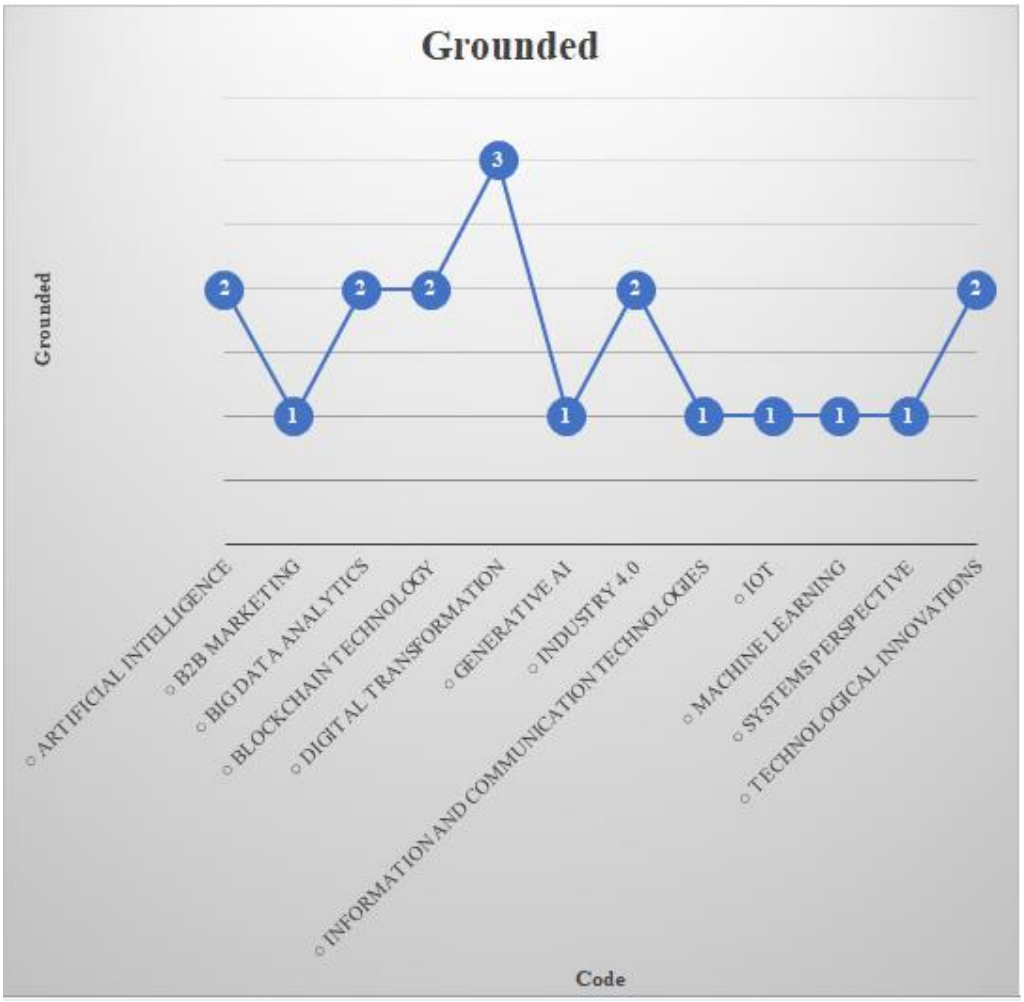

FIGURE 4
GROUNDED CODES GENERATED FROM ATLAS-TI

Source: Authors

4.6 ***Thematic analysis results***

Table 4 below summarises the extracted codes into cohesive themes and provides a systematic overview of the important findings about the emerging paradigms in operations management during the transition from Industry 4.0 to Industry 5.0, each illustrated with a quote from the Atlas-ti report. In this article, we delve into the transformative impact of the progression from Industry 4.0 to Industry 5.0 on operations management within South African supply chains. The findings, synthesised from the systematic review and thematic analysis, are categorised into four main themes that encapsulate the essence of this transition. These themes reflect the integration of advanced technologies, optimisation of operational and business processes, enhancement of strategic decision-making and market performance, and the incorporation of sustainability and innovation in business practices.

4.7 *Technological integration and advancement*

The first theme emphasises the significant impact of technology integration and innovation, focusing on the adoption of Artificial Intelligence, Generative AI, Blockchain Technology, Big Data Analytics, and IoT. This integration of technologies is crucial for transforming industrial processes, allowing managers to enhance operational efficiency, product design, and quality control. Generative AI has the ability to transform systems towards greater autonomy and intelligence, aligning with the characteristics of Industry 5.0 paradigms. These developments promote improved manufacturing flexibility and push the sector towards a future where intelligent, interconnected technology increases operational performance.

4.8 *Operational and business process optimisation*

Industry 5.0 is characterised by notable improvements in operational and business process optimisation via the use of digital transformation strategies, Industry 4.0 principles, and advanced information and communication technology. This theme represents a shift towards smooth, integrated processes that utilise data-driven insights to achieve operational excellence. Digitalisation enhances the efficiency and effectiveness of operational processes by combining lean management with Industry 4.0 technologies, resulting in optimised and resilient supply chains that can adapt to changing market demands.

4.9 *Strategic decision-making and market performance*

The report highlights the significant impact of modern data analytics and AI on strategic decision-making and market performance. The incorporation of big data analytics in B2B marketing and firm performance areas indicates a shift towards data-driven rationality in decision-making processes. This change is crucial for using customer, user, and external market insights to improve B2B marketing strategies, ultimately boosting company performance and competitive standing in the market. Industry 5.0 focuses on utilising digital intelligence to enhance business value and market responsiveness, as demonstrated by its strategic direction.

4.10 *Sustainability and innovation in business practices*

The findings emphasise the increasing focus on sustainability and innovation in company practices, reflecting the broader societal and environmental concerns associated with Industry 5.0. Digitalisation's intricate relationship with business sustainability reveals a scenario where technological integration is more and more connected to sustainable progress. Aligning with sustainability is essential for developing business models that are technologically innovative, environmentally friendly, and socially responsible, in line with the global trend towards sustainability.

The shift from Industry 4.0 to Industry 5.0 in South African supply chains involves several effects on operations management, including technological progress, operational efficiency, strategic insight, and sustainable innovation. The interwoven themes demonstrate a shift towards a more intelligent and sustainable industrial landscape, marking a new era in operations management that follows the principles of Industry 5.0.

Table 4. Main themes, the codes, and short quotes

Main Themes	Codes Linked	Short Quotes
Technological Integration and Advancement	Artificial Intelligence, Generative AI, Blockchain Technology, Big Data Analytics, IoT	" *Generative AI... allows managers to transform manufacturing by optimising processes, improving product design, enhancing quality control*."
Operational and Business Process Optimization	Digital Transformation, Industry 4.0, Information and Communication Technologies	*" The impact of Industry 4.0 technologies on... the implications of their combination on operational excellence."*
Strategic Decision-Making and Market Performance	B2B Marketing, Firm Performance, Knowledge Management	*" Big data powered artificial intelligence... have a significant effect on the B2B marketing-rational decision*

		making."
Sustainability and Innovation in Business Practices	Corporate Sustainability Practices, Environmental Innovation, Social Innovation	*" The role of digitalisation... and the effect of the concurrent adoption of multiple DTs (degree of digitalisation)."*

Source: Authors

5. Discussion

5.1 *Interpretation of the key findings*

The debate in our study explores the detailed consequences of the shift from Industry 4.0 to Industry 5.0 in South African supply chains, specifically focusing on operations management. This change signifies a move towards more interconnected, intelligent, and responsive manufacturing ecosystems, which has significant consequences for the structuring, management, and optimisation of supply chains.

5.2 *Interconnected technologies and operations management*

The incorporation of cutting-edge technologies like AI, IoT, and blockchain is pivotal in the shift from Industry 4.0 to Industry 5.0, fundamentally reshaping the field of operations management. These technologies improve operational efficiency and allow for data-driven decision-making and autonomy that was before unachievable. Technological integration in South African supply chains has the potential to significantly impact the region due to its distinct problems and opportunities. Research conducted by Frank, Dalenogare and Ayala (2019) and Lu (2017) highlights how these technologies might improve supply chain resilience and efficiency, especially in light of South Africa's logistical and infrastructure obstacles.

5.3 *Artificial Intelligence (AI) and operations management*

Incorporating AI into operations management represents a major advancement towards intelligent automation, predictive analytics, and improved decision-making abilities. AI plays a role in optimising production scheduling, inventory management, demand forecasting accuracy, and predictive maintenance. Utilising AI technologies enables companies to reach unparalleled levels of operational efficiency, agility, and responsiveness to market fluctuations. Othman, Bahrin and Azli (2016) explain that AI applications in manufacturing result in smart factories, characterised by interconnected systems that are self-optimizing and capable of making autonomous informed judgements. AI's predictive powers allow for proactive supply chain risk management, improving resilience and competitiveness, as demonstrated by Ivanov and Dolgui (2019).

5.4 *Internet of Things (IoT) and enhanced connectivity*

IoT technology creates a closely interconnected operational setting, where real-time data from different sources are smoothly combined, allowing for a comprehensive understanding of the supply chain. The IoT devices enable seamless data flow, allowing for real-time tracking, monitoring, and resource management. Establishing connectivity is essential for attaining operational transparency, optimising logistics, and improving supply chain visibility. According to Bi, Da Xu and Wang (2014), the Internet of Things (IoT) enables organisations to move towards Industry 4.0, where operational processes are networked, intelligent, and data-driven, leading to more integrated and responsive supply chain ecosystems.

5.5 *Blockchain for enhanced security and transparency*

Blockchain technology revolutionises the sharing of information and recording of transactions in supply networks. The system provides an unchangeable record, allowing clear, safe, and effective transactions throughout the supply chain network. Blockchain enhances supply chain operations by maintaining data integrity and fostering trust among stakeholders. This technology has a significant influence on streamlining procurement processes, boosting product traceability, and guaranteeing the authenticity of items. Saberi, Kouhizadeh, Sarkis and Shen (2019)) explore the transformative impact of integrating blockchain technology into supply chains, enhancing transparency, minimising fraud, and boosting supply chain efficiency.

5.6 *Synthesis of Interconnected Technologies*

The integration of AI, IoT, and blockchain in operations management signifies a new era of industrial capacity, marked by improved efficiency, reliability, and flexibility. The interconnection of various technologies creates a collaborative ecosystem in which machines, systems, and individuals communicate smoothly, allowing for predictive insights and immediate decision-making. An advanced technical environment is crucial for South African supply chains, providing a mechanism to address local and global concerns, improve competitiveness, and promote sustainable growth. The deliberate incorporation of these technologies is in line with the goals of Industry 5.0, emphasising customised, cooperative, and environmentally conscious manufacturing models, as proposed by the visionary perspectives of Zhong, Xu, Klotz and Newman (2017) and Lasi, Fettke, Kemper, Feld and Hoffmann (2014).

5.7 *Strategic decision-making enhancement*

Industry 5.0's impact on strategic decision-making, enhanced by the use of big data analytics and AI, aligns with Kapoor, Vyas and Dadarwal (2018) research, emphasising the need for data-driven strategies in managing current supply chain challenges. South African businesses must possess these talents to maintain competitiveness and promote growth in a continuously changing market environment. Utilising real-time data and predictive insights enables companies to make better decisions, allocate resources more efficiently, and predict market trends more accurately (Wang, Wan, Li & Zhang, 2016; Schwab, 2017).

5.8 Enhanced decision-making through big data analytics

Big data analytics has transformed the field of strategic decision-making. Organisations can use data analysis to make better decisions, predict market changes, and respond to client needs more effectively. Gunasekaran, Papadopoulos, Dubey, Wamba, Childe, Hazen and Akter (2017) demonstrate how big data analytics enables organisations to enhance their strategy in real-time by providing insights into market dynamics, operational inefficiencies, and customer preferences. Big data can improve the agility and resilience of operations in South Africa, where supply chain interruptions are frequent, helping companies stay competitive.

5.9 *AI-Driven predictive analytics in operations management*

Artificial intelligence, especially through machine learning and predictive analytics, is essential for improving strategic decision-making. AI algorithms can forecast future trends, simulate different scenarios, and offer recommendations to assist executives in making strategic decisions. Integrating AI-driven insights into strategic planning improves the precision of forecasting, risk evaluation, and resource distribution. Wamba and Queiroz (2022) state that artificial intelligence's predictive powers are crucial for enhancing supply chain operations, cutting costs, and enhancing efficiency. South African businesses can greatly benefit from using AI to efficiently manage the intricacies of both local and global market landscapes.

5.10 *Integrating IoT for real-time decision support*

The Internet of Things (IoT) enhances strategic decision-making by offering a constant flow of real-time data from interconnected devices throughout the supply chain. The data created by IoT provides an unparalleled level of visibility and control over operations, giving insights that support prompt and well-informed decisions. Porter and Heppelmann (2014) explain that incorporating IoT technologies enables the shift towards intelligent, interconnected operations, where strategic decisions are guided by thorough, up-to-date data, leading to a substantial improvement in operational responsiveness and strategic flexibility.

5.11 *Synergy of interconnected technologies in strategic frameworks*

The combination of big data analytics, AI, and IoT creates a powerful strategic framework that significantly improves decision-making processes. The interconnected technology environment provides decision-makers with a comprehensive and detailed insight of the organisation's operational surroundings, enabling them to make strategic choices based on a holistic picture of influencing elements. An integrated strategy is highly advantageous for South African supply chains as it equips them with the necessary tools to foresee and overcome difficulties related to economic volatility, logistical limitations, and global competition.

5.12 Sustainability and innovation nexus

The focus on sustainability and innovation mirrors a wider industry movement towards incorporating environmental and social governance (ESG) concepts into fundamental business strategies. This is consistent with the viewpoints of authors such as Govindan and Hasanagic (2018) and Beske, Land and Seuring (2014), who emphasise the growing significance of sustainability in supply chain management. South Africa, facing environmental issues and socio-economic imbalances, can achieve more responsible and inclusive industrial development by incorporating sustainability practices using Industry 5.0 technologies.

5.13 *Embedding sustainability through technological advancements*

Integrating Industry 5.0's sophisticated technologies like AI, IoT, and blockchain with sustainability initiatives signifies a significant advancement in operational procedures. These technologies help organisations improve operational efficiency and greatly decrease their environmental impact. AI can enhance resource allocation, significantly reducing waste and enhancing energy efficiency, which is essential for sustainable operations management (Dao, Langella & Carbo, 2011) IoT devices provide for real-time monitoring of environmental conditions to ensure adherence to sustainability requirements and enable proactive management of ecological impacts (Perera, Liu, Jayawardena & Chen, 2014).

5.14 *Driving sustainable innovation*

In this context, innovation involves not only technology progress but also the reconsideration of business structures and procedures to incorporate sustainability as a fundamental aspect. Sustainable innovation involves generating value that considers economic growth, environmental stewardship, and social well-being. Innovation is crucial in South Africa, where balancing economic progress with socio-environmental obligations is a serious issue. Industry 5.0 digital technologies provide the means to develop in a manner that supports a circular economy focused on resource efficiency and waste reduction (Geissdoerfer, Savaget, Bocken & Hultink, 2017).

5.15 Sustainability practices as competitive advantage

Implementing sustainability strategies provides a strategic competitive edge by adhering to global environmental and social governance requirements and meeting the growing customer demand for ethical business operations. Businesses that embrace sustainable technologies are expected to see improvements in their brand reputation, consumer loyalty, and cost savings due to effective resource management (Porter & Kramer, 2006; Latapí Agudelo, Jóhannsdóttir & Davídsdóttir, 2019). Utilising these methods in the South African supply chain framework can offer enterprises a unique advantage in local and global markets.

5.16 *Collaborative ecosystems for sustainable outcomes*

Industry 5.0 promotes a collaborative environment where industry, government, academia, and civil society can come together to advance sustainability. Collaboration is crucial for addressing intricate environmental issues and making the systemic adjustments necessary for sustainable development (Kusi-Sarpong, Gupta & Sarkis, 2019). Through collaboration, stakeholders may exchange knowledge, collectively develop sustainable solutions, and amplify innovative ideas with the capacity to revolutionise entire sectors.

5.17 *Proposing an innovative model: the integrative industry 5.0 operations management (ii5om) model*

We introduce the Integrative Industry 5.0 Operations Management (II5OM) Model, a conceptual framework that aims to leverage the interactions between technological progress and operations management within the Industry 5.0 setting. This model consists of four essential components:

- Techno-Operational Synergy: Centralises the integration of AI, IoT, and blockchain with operational processes, enhancing transparency, efficiency, and adaptability.
- Data-Driven Strategic Insight: Emphasises the role of big data and analytics in informing strategic decision-making, fostering a proactive, predictive approach to supply chain management.
- Sustainable Innovation Interface: Aligns technological advancements with sustainability goals, promoting eco-friendly practices and sustainable value creation.

- Resilient Supply Chain Architecture: Advocates for the design of supply chains that are robust, agile, and adaptable to the dynamic global landscape, leveraging Industry 5.0 technologies for enhanced resilience.

The Integrative Industry 5.0 Operations Management (II5OM) Model is depicted in Figure 5 as a flow diagram consisting of three interconnected components. Each element is depicted as a rectangular box with a rounded corner and includes bullet points that provide detailed explanations of the element's key areas of concentration. The components are named " Techno-Operational Synergy," " Data-Driven Strategic Insight," and " Resilient Supply Chain Architecture." Arrows represent the movement and interconnectedness among various elements, suggesting a cyclical or repeating procedure. The boxes contain text detailing the ideas and objectives linked to each part of the model. The II5OM Model aims to depict the shift from Industry 4.0 to Industry 5.0 in operations management, specifically focusing on South African supply chains. The approach starts with " Techno-Operational Synergy," highlighting the importance of incorporating sophisticated technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain to improve operational procedures, transparency, efficiency, and flexibility. This implies a fundamental level where technology is used to enhance operational efficiency. The second component, " Data-Driven Strategic Insight," emphasises the significance of big data and analytics in strategic decision-making. It promotes a proactive and predictive strategy for supply chain management, indicating that well-informed insights can result in more agile and anticipatory operations. The " Resilient Supply Chain Architecture" emphasises creating supply networks that are strong, flexible, and able to adjust to the changing global environment by utilising Industry 5.0 technologies to improve resilience. This highlights the necessity for supply chain frameworks that are resilient and flexible in the face of different interruptions and alterations, while also encouraging environmentally friendly activities and the production of sustainable value. The concept advocates a comprehensive and unified strategy for operations management, crucial for transitioning from Industry 4.0 to Industry 5.0. The change is marked by a more profound incorporation of technology, data-centric approaches, and dedication to sustainable and resilient supply chain structures.

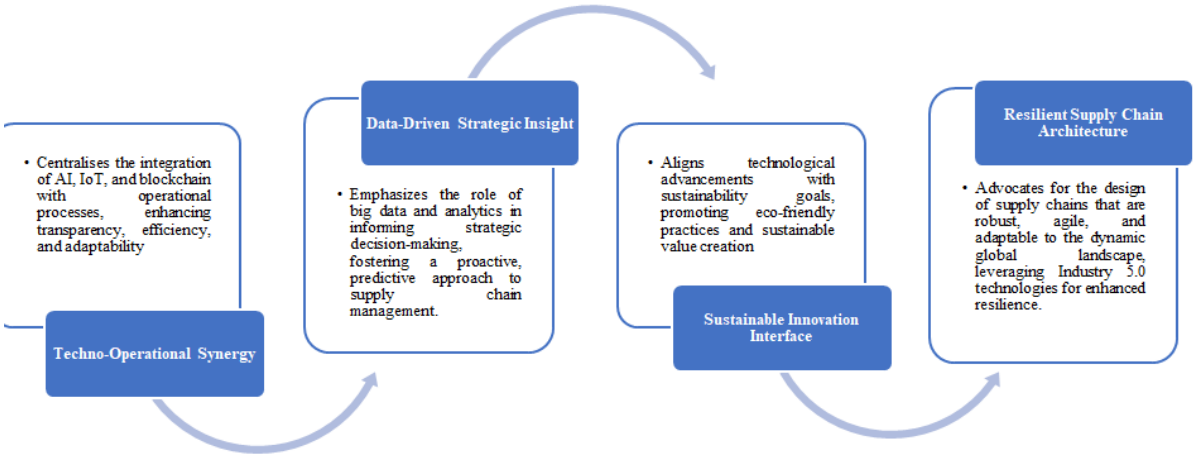

FIGURE 5
THE INTEGRATIVE INDUSTRY 5.0 OPERATIONS MANAGEMENT (II5OM) MODEL
Source: Authors

The II5OM Model aids academics and industry by offering a systematic method for managing the challenges of transitioning from Industry 4.0 to 5.0, focusing on integrating technology, strategy, sustainability, and resilience in a balanced manner. It provides guidance for firms looking to take advantage of the upcoming

industrial innovation, presenting a plan for developing operations management skills that are prepared for the future and in line with international standards.

The argument highlights the many effects of the transition from Industry 4.0 to 5.0 on operations management in South African supply chains. The text emphasises the significant influence of technology on changing strategy frameworks, the crucial function of making decisions based on data, and the increasing necessity of incorporating sustainability. The II5OM Model encompasses various characteristics, providing a thorough framework that contributes to scholarly discussions and offers practical guidance for firms adapting to the changing industrial environment.

5.16 ***Implications for practitioners and policymakers***

The shift from Industry 4.0 to Industry 5.0 brings about a dramatic change in operations management and supply chain paradigms, impacting practitioners and policymakers. This transformation, marked by the incorporation of cutting-edge technologies, improved strategic decision-making, and a significant focus on sustainability and innovation, requires a reassessment of existing practices and policy structures. Practitioners and policymakers in these disciplines must have a deep awareness of the ongoing developments and take a proactive approach to capitalise on the opportunities they offer.

5.17 ***Implications for practitioners***

Practitioners in operations management and supply chains are urged to adopt a new era of interconnected technologies with the transition to Industry 5.0. Combining AI, IoT, and blockchain technology requires a reassessment of conventional operational procedures. Practitioners need to acquire skills in these technologies, comprehending both their functional abilities and their strategic consequences. Utilising data-driven insights can greatly boost decision-making, leading to improved operational efficiencies, cost reduction, and better responsiveness to market changes. Hence, continuous education and training in these technology fields are essential for sustaining a competitive edge. Furthermore, practitioners must take a comprehensive approach to the supply chain, taking into account the economic, environmental, and social implications of their operations due to the focus on sustainability and innovation. This change requires the creation of innovative strategies that integrate sustainability into the fundamental aspects of corporate operations, encouraging methods that guarantee long-term sustainability and adaptability. Practitioners must balance operational efficiency with sustainable outcomes by employing innovative thinking and strategic vision.

5.18 ***Implications for policymakers***

Policymakers have a crucial influence on the ecosystem in which the transition to Industry 5.0 takes place. They are responsible for establishing a legislative framework that fosters innovation and guarantees that the advantages of technological progress are widely distributed and enduring. This requires creating regulations that promote the implementation of Industry 5.0 technologies, including offering incentives for investing in AI, IoT, and blockchain, as well as establishing frameworks that support data exchange and cybersecurity. Policymakers must also consider the labour implications of this technological change. With the increasing automation and data-driven nature of operations, there is an urgent requirement for reskilling and upskilling programmes to equip the workforce for future job roles. Implementing policies to promote lifelong learning and continual professional development is crucial to prepare personnel with the necessary skills for an Industry 5.0-driven environment. Policies promoting sustainable industrial practices and green technology development are crucial for the sustainability and innovation nexus. Policymakers should prioritise incorporating sustainability objectives into industrial policy to stimulate innovative practices by companies that promote environmental preservation and societal welfare. This may include establishing sustainability criteria, offering assistance for eco-friendly advancements, and promoting cooperation among industry, academia, and government to encourage sustainable growth.

5.19 ***A collaborative approach***

The shift to Industry 5.0 requires a cooperative effort between professionals and decision-makers to address the challenges and opportunities of this new phase. Practitioners should collaborate with legislators to shape regulatory frameworks, and officials should consider industry demands to create relevant and successful legislation. Collaboration may help organisations smoothly move to Industry 5.0, allowing them to utilise new technology and create a sustainable and inventive growth environment.

5. CONCLUSION

Our study reveals the significant changes in operational and supply chain frameworks due to the shift from Industry 4.0 to Industry 5.0. This transition signifies a major advancement in operations, introducing improved connectivity, more intelligent decision-making, and a stronger focus on sustainability and innovation. Our research discovered important information about how the incorporation of sophisticated technologies such as AI, IoT, and blockchain is transforming operations management, creating a smooth, effective, and forward-looking operational setting. The results emphasise the crucial importance of using data-driven strategic decision-making, showing how real-time analytics and AI-driven insights are essential for creating well-informed, adaptable, and future-oriented operational strategies. In addition, the close connection between sustainability and innovation in this technological shift suggests a future where operational efficiency is in line with environmental protection and social accountability. The shift from Industry 4.0 to Industry 5.0 significantly affects operations management in South African supply chains by fostering technological advancement, streamlining processes, improving strategic flexibility, and encouraging sustainability. This transition involves more than just technology changes; it represents a comprehensive transformation that includes strategic, cultural, and operational aspects to help organisations stay competitive, adaptable, and in line with global sustainability goals. Future studies should focus on conducting longitudinal studies to monitor the continuous effects of Industry 5.0 innovations on operational performance and supply chain resilience. Empirical studies are urgently required to investigate the particular difficulties and advantages encountered by South African businesses throughout this shift. Industry practitioners must proactively focus on technology upskilling, promote innovation, and integrate sustainability into fundamental business objectives. Policymakers should prioritise establishing favourable conditions for this transition, promoting the adoption of technology, assisting in worker training, and guaranteeing fair distribution of the advantages of Industry 5.0 breakthroughs. Our study offers detailed insights but is limited by the scope of material studied, mostly centred on the South African context. Future research could broaden the scope of this study to a worldwide level, analysing the Industry 4.0 to 5.0 transitions in various economic, social, and industrial settings. Studying the effects on certain sectors and how government policies might help or impede these changes could provide significant insights. The movement from Industry 4.0 to Industry 5.0 in South African supply chains involves technology breakthroughs, strategic changes, and a move towards sustainable operational practices. All stakeholders, including industry leaders, governments, and the academic community, need to make a collective effort to fully utilise the promise of this transformation and address the issues it brings.

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