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Chapter 9. Harnessing Smart Artificial Intelligence for Industrial 4.0: A South African Case Study of Manufacturing Industry

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Abstract

The global trend towards Industry 4.0 has raised demand to incorporate technology in the manufacturing industry. This new paradigm requires cyber-physical systems, the Internet of Things (IoT), and Artificial Intelligence (AI) to enhance the efficiency and competitiveness of traditional industrial methods. Industry 4.0 incorporates Smart Artificial Intelligence (SAI) to enhance efficiency, digitalise production, and automate the intelligent processing of commodities. Despite the benefits SAI technology carries, many South African industries struggle to realise its full potential due to resource and financial constraints. This chapter discusses the challenges of SAI adoption and how the manufacturing sector leverages SAI to enhance its productivity and competitiveness. A systematic literature review was conducted. ScienceDirect publications from 2022-2025 period were reviewed. Only the review and research papers, focusing on the SA manufacturing industry, were considered. The findings reveal how the use of SAI in South Africa (SA) is hindered, thereby constraining innovation and productivity. SAI promotes manufacturing in the country; inadequate infrastructure, a lack of funding are the biggest obstacles to implementing SAI in SA. A contribution about how SAI technology is leveraged in the SA manufacturing industry was established, advancing knowledge that may inform industry leaders.

Keywords: smart artificial intelligence, South Africa, smart manufacturing, industry 4.0, systematic literature review.

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Introduction

Industry 4.0 (I4.0), a Fourth Industrial Revolution initiative, is transforming the manufacturing sector into a more competitive environment by employing technologies such as smart artificial intelligence (SAI), the Internet of Things (IoT), and cyber-physical systems to enhance productivity and efficiency (Adams, 2023). SAI technologies are crucial in this transformation, enabling enhanced automation, predictive analytics, and optimal resource management in complex industrial processes (Akoh, 2024). SAI is generally acknowledged as a crucial technology for advancing the future development of industrial 4.0 manufacturing (Papadimitriou et al., 2024). Consequently, Industry 4.0 emphasises improved efficiency, digitised manufacturing operations, and the systematic processing of intelligent goods (Philbeck & Davis, 2018; Pypenko & Melnyk, 2021). Despite the benefits, many manufacturing companies struggle to implement SAI technologies due to a lack of necessary resources and knowledge (Espina-Romero et al., 2024). This context highlights the need for targeted interventions to bridge the digital divide and enhance technological capacity in SA, particularly to address shortcomings.

Manufacturing Sector in SA

The manufacturing sector is a vital component of South Africa's economy, significantly contributing to its advancement and wealth (Maphisa et al., 2024). Almost 11,400 VAT-licensed firms contribute to South Africa's manufacturing sector, establishing it as a vital component of the national economy (Ngepah et al., 2024). This sector ranks as the fourth-largest industry in SA (Maisiri & Van Dyk, 2021). This chapter categorises the manufacturing industry based on the Manufacturing, Engineering and Related Services industry Education and Training Authority (MerSETA).

Purpose

The purpose of this chapter is to evaluate the approaches in which different manufacturing industries in SA utilise SAI to improve competitiveness and productivity. The objectives of the chapter are: 1) to analyse current SAI adoption within the South African manufacturing sector, and 2) to recommend a shared understanding of the SAI technologies most suitable for the South African manufacturing industry.

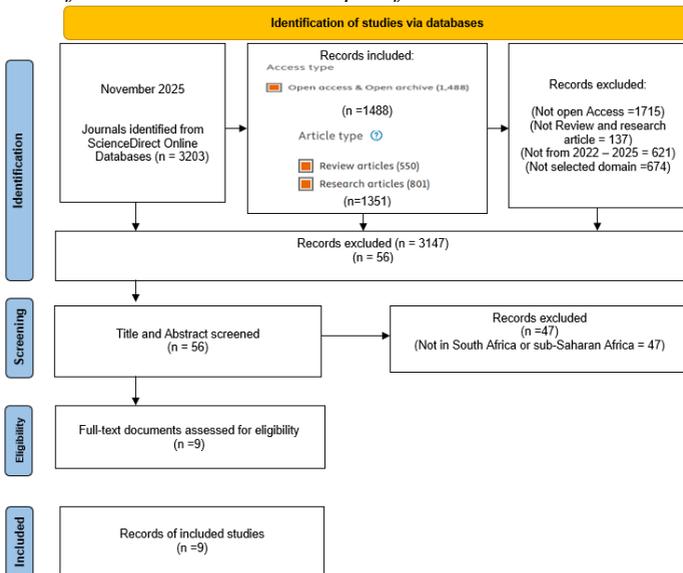
Research Methodology

A systematic literature review (SLR) was utilised as a method to evaluate existing literature. Focuses on studies that discuss SAI technologies in the SA manufacturing settings and were published during the previous five years. SLR was selected as the methodology due to its crucial role in academic research, which can synthesise key theoretical foundations and empirical results within a specific discipline, identify potential research opportunities, and formulate new theories, all

aimed at enhancing knowledge (Webster & Watson, 2002). This review is essential for gaining a comprehensive understanding of the current approaches to AI-driven smart manufacturing technologies in industrial settings.

The credibility and relevance of the review were evaluated in this chapter using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), a standard for systematic reviews and meta-analyses. The PRISMA methodology facilitated a peer-reviewed, systematic approach for article selection, search techniques, data extraction, and data analysis procedures (Page et al., 2021). To improve the clarity and comprehensiveness of reporting in systematic reviews, PRISMA provides a visual representation of a systematic review through a four-phase flowchart, as illustrated in Figure 9.1.

Figure 9.1
Identification of the Selected Studies Adapted from PRISMA 2020



Note. From “The PRISMA 2020 statement: an updated guideline for reporting systematic reviews”, by M. J. Page et al., 2021, *BMJ*, 372, Article 71. (<https://doi.org/10.1136/bmj.n71>). Copyright 2021 BMJ Publishing Group Ltd.

Identification of Studies

Only relevant studies from 2022 to 2025 from ScienceDirect were included. ScienceDirect is a digital library that provides access to peer-reviewed journals, books, and articles across various scientific and technological fields. Due to the

chapter's word limit, only one database was used for the literature analysis. Although other databases may be considered for future studies.

The search keyword was “Artificial Intelligence” OR “AI” AND “manufacturing sector” OR “industry” AND/OR “South Africa”. The preliminary search yielded 3,203 publications in various categories. Filtering for open-access articles yielded 1,488 results. Narrowing the search to just peer-reviewed research and review publications yielded 1353 results. Limiting the search to five-year publications found 730 relevant publications. Only computer science, technology, social science, engineering, energy, humanities, market complexity, technological forecasting, and agriculture research were included, resulting in 56 papers. At least one publication type was chosen to address variations.

Screening of Titles and Abstracts

The selection was determined by screening titles and abstracts that were retrieved and imported into EndNote. The retrieved papers were analysed by screening titles and abstracts that conformed to the identified search term. Only papers contextualised in SA or sub-Saharan Africa were chosen after screening. Sub-Saharan Africa refers to the region of the continent located south of the Sahara Desert, including countries such as SA and others. Consequently, studies within the sub-Saharan region with a focus on SA are viable for analysis.

Eligibility of Studies

A total of nine papers were subsequently confirmed feasible for analysis. A summary of the selected eligible studies is presented in Figure 9.1.

Inclusion Studies

The articles selected for analysis are presented in Table 9.1.

Table 9.1

List of Articles Selected for Analysis

Paper ID	Title and Author	Articles function with search parameters		
		AI	Industry 4.0 or Manufacturing	SA or Sub-Saharan
P1	A critical review of the enablers and constraints of artificial intelligence in the South African public sector (Baloyi et al., 2025)	X		X
P2	Artificial intelligence and industry 4.0 and 5.0: a bibliometric study and research agenda (Fosso-Wamba & Guthrie, 2024)	X	X	
P3	The effects of digital transformation on innovation and productivity: Firm-level evidence of South African manufacturing micro and small enterprises (Gaglio et al., 2022)		X	X

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P4	Synthesising the potential of artificial intelligence in the fulfilment of sustainable development goals in South Africa: An ethical perspective (Mapungwana & Chadyiwa, 2025)	X	X	
P5	Intelligent manufacturing eco-system: A post COVID-19 recovery and growth opportunity for manufacturing industry in Sub-Saharan countries (Mezgebe et al., 2023)		X	X
P6	The impact of Industry 4.0 on South Africa's manufacturing sector (Ngepah et al., 2024)		X	X
P7	Industry 4.0 concepts within the sub-Saharan African SME manufacturing sector (Peter et al., 2023)		X	X
P8	Transformation of South Africa's energy landscape: Policy implications, opportunities, and technological innovations in the Fourth Industrial Revolution (Ukoba et al., 2025)		X	X
P9	A systematic review of fourth industrial revolution technologies in smart irrigation: Constraints, opportunities, and future prospects for sub-Saharan Africa (Wanyama et al., 2024)		X	X

Table 9.2 summarizes the excluded and included studies from the analysis.

Table 9.2

Exclusion and Inclusion Criteria

Exclusions Studies	Inclusions Studies
Studies not in the context of SA	Contextualise for SA or Sub-Saharan
Published before 2022	2022-2025
Not Review and Research articles	Book chapter, conferences, seminars, etc.
Not Open access	Open access
Other discipline	Domain of computer science, technology, social
Not written in English	science, engineering, energy, humanities, market
	complexity, technological forecasting, and smart
	agriculture

The criteria for inclusion and exclusion in this systematic review were strictly enforced to ensure that only relevant studies on SAI technologies in SA manufacturing were included. The identified studies were categorized and analyzed to synthesize approaches regarding the role of SAI in the diverse manufacturing industry.

Findings and Discussion

The systematic literature review highlights the key trends, advantages, and challenges of employing SAI in various sectors of SA manufacturing. P1 reviewed the enablers and constraints to AI adoption for improving public-sector management in South Africa, examining potential opportunities and risks, as well as ethical issues and relevant policies and initiatives. P2 addressed how AI is used in Industry 4.0 for smart manufacturing systems and Industry 5.0 for processes that are sustainable and focused on people. P4 explored how AI affects sustainable development, notably in smart farming, predictive analytics for health and poverty, and related fields. P3, P5, P6, and P7 discussed the significance and industrial relevance of intelligent manufacturing technologies, evaluating the impact of digital transformation on innovation and productivity within South African SMEs and other disciplines. P8 aimed to analyse South Africa's energy environment, focusing on policy implications, the adoption of renewable energy, and the impact of Industrial 4.0 technologies on the industry. P9 Smart Irrigation study examines the capacity of Industrial 4.0 technology to address agricultural issues in sub-Saharan Africa. These studies together underscore the emerging yet increasing interest in SAI integration within South Africa's economic sectors, despite considerable obstacles.

The benefits of SAI in the Manufacturing Public Sector Adoption

AI demonstrates substantial potential for enhancing operational efficiency, streamlining service delivery, and decreasing administrative burdens (Mahusin et al., 2024). P1 attests that SAI adoption has several advantages in service delivery, for example, the implementation of the Automated Biometric Identification System, an AI-based system intended to match individuals' fingerprints, facial features, and palm prints, as well as robotics, facial recognition, and virtual agents (Baloyi et al., 2025; Marakalala & Matlala, 2024).

Challenges of SAI in the Manufacturing Public Sector Adoption

Despite the recognised potential for efficiency gains and enhanced service delivery, ethical and governance concerns, alongside a lack of tailored frameworks, significantly impede its full integration (Baloyi et al., 2025). A primary factor hindering the widespread adoption of SAI in SA is the lack of suitable or inadequate policies, legislation, and regulations governing digital technology (Rekunen et al., 2025). Additionally, there are frequent ethical dilemmas caused by regulatory concerns. Such as data protection, privacy, security, accountability, openness, and public confidence, as ethical considerations (Chilunjika, 2024). As a result, public sector management in Africa is particularly vulnerable to cyberattacks and data hacking (Pieterse, 2021). Nevertheless, AI-driven technologies have been widely used in various industries like healthcare, education, transportation, and municipal services, greatly improving human lives and making public services more accessible (Alaran et al., 2025). Thus, they are lauded as an effective instrument for addressing massive public sector issues.

The Benefits of SAI in the Manufacturing Energy Sector Adoption

The energy sector in SA is undergoing a significant transformation, driven by technological innovations, policy changes, and the global shift towards sustainable energy systems (Langerman et al., 2023). The country has historically relied on coal for electricity generation, with more than 80% of its power supply derived from coal-fired plants (Pegels, 2010). This exhibits moderate advancement in the integration of Industry 4.0, largely propelled by initiatives in renewable energy. The sector is currently undergoing a significant transformation, with Industrial 4.0 technologies, including smart grids and decentralized energy systems, providing essential pathways for achieving sustainable energy objectives (Hassan et al., 2023). P8 elaborated how the existing renewable energy capacity comprises 2500 MW of solar photovoltaic and 3670 MW of wind energy, with projections aiming for 40% renewable energy by 2030 (Ukoba et al., 2025).

The Challenges of SAI in the Manufacturing Energy Sector Adoption

Nonetheless, the sector encounters considerable challenges due to its substantial dependence on coal, which constitutes 77% of electricity generation, whereas renewable energy accounts for merely 12% (Dhansay et al., 2017). Disparities in rural electrification persist, underscoring the need for inclusive energy solutions. The findings indicate that although policy frameworks are in place, there is a need to enhance regulatory frameworks to expedite the adoption of renewable energy and tackle energy poverty through decentralized systems.

The Benefits of SAI in the Agricultural Sector Adoption

The implementation of Industrial 4.0 technologies has transformed agricultural approaches globally. The adoption of smart irrigation, utilising AI, provides significant advantages in optimising water usage and enhancing crop yields (Formanek et al., 2024). Smart irrigation extensively integrates Industry 4.0 technologies, including drones, AI, the IoT, Big Data technology, and Blockchain (Wanyama et al., 2024).

These innovations enable the tracking of soil moisture and weather in real-time, allowing for the planning of irrigation with pinpoint accuracy, optimizing water distribution, and providing insight into how crops utilize water in real-time (Odhiambo et al., 2021). However, smart irrigation in agriculture particularly shows promise, but is not yet widely used in SA.

New irrigation technologies worldwide demonstrate potential for enhancing agricultural output and mitigating the effects of climate change, despite persistent water shortages (Lebek & Krueger, 2023). Integration of new technologies like 3D printing, drones, robots, blockchain, and the IoT is defining the Industrial 4.0 that the world is seeing right now (Jacoby, 2023). Smart and precise irrigation, made possible by these developing intelligent technologies, is set to revolutionize farming in sub-Saharan Africa (Nigussie et al., 2020). However, challenges persist in the adoption in sub-Saharan Africa.

The Challenges of SAI in the Agricultural Sector Adoption

P9 is evident that the lack of technical knowledge, inadequate infrastructure, and limited access to technology are significant obstacles to adoption (Wanyama et al., 2024). The high starting prices of these technologies also make it difficult to be widely adopted. Although the technology promise is there, the findings show that specific structural restrictions are limiting current usage. Nonetheless, their implementation in sub-Saharan Africa presents a significant challenge, despite the pressing requirement for sustainable and data-driven irrigation systems to secure food and promote economic development in the region (Wanyama et al., 2024).

The Benefits of SAI in the SMEs Manufacturing Sector

Selected digital communication technologies, such as social media and mobile phones for internet access, have a positive influence on innovation, which in turn enhances labour productivity, contingent upon the use of these technologies (Gaglio et al., 2022). This indicates fundamental digitalisation rather than a thorough implementation of Industry 4.0. P6 indicates that AI significantly enhances productivity, sustainability, and decision-making through the use of AI-driven machine learning models as part of Industry 4.0 initiatives. AI systems were integrated with IoT sensors installed on industrial equipment, such as IoT, robotics, and cyber-physical systems, thereby increasing productivity and output quality (Ngepah et al., 2024).

The Challenges of SAI in the SMEs Manufacturing Sector

In developing nations like SA, SMEs within the manufacturing sector are either not adopting or are slowly integrating Industry 4.0 approaches, resulting in decreased competitiveness. P5 and P7 indicated how the sector faces significant challenges in implementing Industry 4.0 among manufacturing SMEs in emerging economies (Mezgebe et al., 2023; Peter et al., 2023).

Lack of investment in these technologies, dealing with weak intellectual property rights, data privacy restrictions, Industry 4.0 specialised skills shortages, and local skills shortages (Peter et al., 2023). The Coronavirus Disease of 2019 pandemic significantly affected the manufacturing sector in sub-Saharan countries, delaying the adoption (Mezgebe et al., 2023). This indicates that the sector necessitates immediate intervention to avert additional competitive disadvantage.

Recommendation

AI offers significant economic and social benefits, but successful adoption in SA depends on addressing infrastructure gaps, skills shortages, and policy alignment (Mapungwana & Chadyiwa, 2025). P2 emphasises that SA requires a balance between the efficiency gains of Industry 4.0 and the human-centric principles of Industry 5.0. This will ensure that AI promotes economic development, sustainability, and social inclusion simultaneously (Fosso-Wamba & Guthrie, 2024). Consequently, SA needs to respond to the global adoption of Industry 4.0 by embracing innovative technologies and fostering a culture of continuous learning and adaptation. A summary of the South African SAI adoption challenges

and benefits elaborates on how the diverse manufacturing sector in SA leverages SAI for competitiveness (see Table 9.3).

Table 9.3
SAI Adoption Challenges and Benefits in SA

Paper ID	Findings	Benefits	Challenges	Recommendation
P1	Machine learning (ML), robotics, facial recognition, virtual agents, and biometric identification systems	SAI offers efficiency, cost savings, productivity gains, and improved service delivery	AI adoption remains nascent and fragmented inadequate policies	Invest in the training/ reskilling of public servants, foster an innovative digital culture, ring-fence funding for AI and related digital infrastructure, and pursue targeted pilots before scaling up
P2	Deep Learning, Predictive Maintenance, and Data Mining	Better asset management and Improved decision-making across sectors	High capital costs for SMEs	Deep Learning, Predictive Maintenance, and Data Mining
P3	Digital communication technologies, including the use of social media and a business mobile phone	Positive effect on labor productivity	Accessibility on advanced digital technologies	Public programs aimed at fostering inclusive digitalization must consider the types of digital technologies that are most accessible and beneficial to small firms
P4	Automation, smart factories, and real time analytics	Analytics use for forecasting, fault detection. Reduced operational costs	High implementation and maintenance costs. Skills shortages in AI and data science	Provide incentives for SMEs to adopt AI. Invest in national data and computing infrastructure
P5	Intelligent technologies	Enhanced global competitiveness, adapted as a post-COVID-19 recovery and growth opportunity to enhance production processes of the manufacturing industry	Technological lag and pandemic impacts	Proposition of a Triple Helix Collaboration Eco-system that delineates a recursive contribution of Government, academia, and industry

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P6	Automated decision-making fault detection, and maintenance planning	Increased productivity and output quality. Reduced operational cost	High cost of adoption for SMEs	Provide financial incentives for AI adoption
P7	A network digitization, automation	Reduced downtime, better resource utilization, supply chain visibility	Skills deficit for I4.0 specialists, high capital needs amid electricity shortages, low organizational readiness, and lack of standards/ training	Establish pan-African commissions for guidance/digital assessment; create pilot labs; run digital literacy programs; build foreign expert networks; develop leadership frameworks and global benchmarks
P8	Smart grids and decentralized energy systems	Sustainable energy in SA	Dependence on coal	Energy solutions and regulatory frameworks to expedite the adoption of renewable energy
P9	Data-driven irrigation systems, drones, the IoT, Big Data technology, and Blockchain	Secure food and promote economic development in the country. optimising water usage and enhancing crop yields	Regional infrastructural and economic challenges	Leverage existing mobile phone penetration for IoT data collection, collaborative partnerships, and innovative financing models

Conclusion

Regardless of diverse sectors, the selected studies show that inadequate infrastructure, lack of funding, and the need to increase capacity are the biggest obstacles to implementing SAI in SA. Manufacturing studies reveal challenges that necessitate systemic remedies, whereas energy and agriculture studies offer more optimistic projections, accompanied by specific investment and timelines. This indicates that the adoption of SAI in South Africa's industrial sector is crucial.

Limitations

The chapter focused solely on manufacturing, drawing insights from the selected literature papers, whereas a multi-sectoral analysis may provide more comprehensive insights.

Recommendation

In response to the global adoption of Industry 4.0, SA needs to respond by embracing innovative technologies and fostering a culture of continuous learning and adaptation. The global community, including China, has responded by developing initiatives that support the manufacturing industry in line with Industry

4.0 (Kang et al., 2016). This has led to increased efficiency, productivity, and competitiveness in the manufacturing sector. The outcome of this chapter may provide industry leaders with knowledge on adopting SAI to enhance operational efficiency, thereby contributing to improved economic viability and environmental sustainability.

References

- Adams, D. (2023). Smart factory concept for an agri-processing plant in the Western Cape. *South African Journal of Industrial Engineering*, 34(3), 198–214. <https://doi.org/10.7166/34-3-2950>
- Akoh, E. I. (2024). Adoption of artificial intelligence for manufacturing SMEs' growth and survival in South Africa: A systematic literature review. *International Journal of Research in Business and Social Science*, 13(6), 23–37. <https://doi.org/10.20525/ijrbs.v13i6.3561>
- Alaran, M. A., Lawal, S. K., Jiya, M. H., Egya, S. A., Ahmed, M. M., Abdulsalam, A., Haruna, U. A., Musa, M. K., & Lucero-Prisno III, D. E. (2025). Challenges and opportunities of artificial intelligence in African health space. *Digital Health*, 11. <https://doi.org/10.1177/20552076241305915>
- Baloyi, W. M., Meyer, N., & Rossouw, D. (2025). A critical review of the enablers and constraints of artificial intelligence in the South African public sector. *Journal of Contemporary Management*, 22(1), 380–403. <https://doi.org/10.35683/jcman1185.302>
- Chilunjika, A. (2024). A review of the risks, challenges and benefits of using artificial intelligence (AI) technologies in public policy-making in South Africa. *Artificial Intelligence Social Sciences, Humanities and Education Journal*, 53, 393–411. <https://hdl.handle.net/10210/512650>
- Dhansay, T., Musekiwa, C., Ntholi, T., Chevallier, L., Cole, D., & De Wit, M. J. (2017). South Africa's geothermal energy hotspots inferred from subsurface temperature and geology. *South African Journal of Science*, 113(11-12), 1–7. <https://doi.org/10.17159/sajs.2017/20170092>
- Espina-Romero, L., Gutiérrez Hurtado, H., Ríos Parra, D., Vilchez Pirela, R. A., Talavera-Aguirre, R., & Ochoa-Díaz, A. (2024). Challenges and opportunities in the implementation of AI in manufacturing: A bibliometric analysis. *Sci*, 6(4), Article 60. <https://doi.org/10.3390/sci6040060>
- Formanek, C., Tilbury, C. R., & Shock, J. P. (2024). *Opportunities of reinforcement learning in South Africa's just transition*. arXiv. <https://arxiv.org/abs/2411.15145>
- Fosso-Wamba, S., & Guthrie, C. (2024). Artificial intelligence and industry 4.0 and 5.0: A bibliometric study and research agenda. *Procedia Computer Science*, 239, 718–725. <https://doi.org/10.1016/j.procs.2024.06.228>
- Gaglio, C., Kraemer-Mbula, E., & Lorenz, E. (2022). The effects of digital transformation on innovation and productivity: Firm-level evidence of

- South African manufacturing micro and small enterprises. *Technological Forecasting and Social Change*, 182, Article 121785. <https://doi.org/10.1016/j.techfore.2022.121785>
- Hassan, Q., Sameen, A. Z., Salman, H. M., Al-Jiboory, A. K., & Jaszczur, M. (2023). *The role of renewable energy and artificial intelligence towards environmental sustainability and net zero*. Research Square. <https://doi.org/10.21203/rs.3.rs-2970234/v1>
- Langerman, K. E., Garland, R. M., Feig, G., Mpanza, M., & Wernecke, B. (2023). South Africa's electricity disaster is an air quality disaster, too. *Clean Air Journal*, 33(1). <https://doi.org/10.17159/caj/2023/33/1.15799>
- Lebek, K., & Krueger, T. (2023). Conventional and makeshift rainwater harvesting in rural South Africa: Exploring determinants for rainwater harvesting mode. *International Journal of Water Resources Development*, 39(1), 113–132. <https://doi.org/10.1080/07900627.2021.1983778>
- Mahusin, N., Sallehudin, H., & Satar, N. S. M. (2024). Malaysia public sector challenges of implementation of artificial intelligence (AI). *IEEE Access*, 12, 121035–121051. <https://doi.org/10.1109/ACCESS.2024.3448311>
- Maisiri, W., & Van Dyk, L. (2021). Industry 4.0 skills: A perspective of the South African manufacturing industry. *SA Journal of Human Resource Management*, 19, Article 1416. <https://doi.org/10.4102/sajhrm.v19i0.1416>
- Maphisa, X., Nkadimeng, M., & Telukdarie, A. (2024). Contextual intelligence: An AI approach to manufacturing skills' forecasting. *Big Data and Cognitive Computing*, 8(9), Article 101. <https://www.mdpi.com/2504-2289/8/9/101>
- Mapungwana, P., & Chadyiwa, M. (2025). Synthesising the potential of artificial intelligence in the fulfilment of sustainable development goals in South Africa: An ethical perspective. *Social Sciences & Humanities Open*, 12, Article 101883. <https://doi.org/10.1016/j.ssaho.2025.101883>
- Marakalala, M. C., & Matlala, M. M. (2024). Border management identification: The biometric technology to detect criminals and terrorists often travel using falsified identity documents. *OIDA International Journal of Sustainable Development*, 17(12), 59–70. <https://ssrn.com/abstract=5006155>
- Mezgebe, T. T., Gebresslassie, M. G., Sibhato, H., & Bahta, S. T. (2023). Intelligent manufacturing eco-system: A post COVID-19 recovery and growth opportunity for manufacturing industry in Sub-Saharan countries. *Scientific African*, 19, Article e01547. <https://doi.org/10.1016/j.sciaf.2023.e01547>
- Ngepah, N., Saba, C. S., & Kajewole, D. O. (2024). The impact of industry 4.0 on South Africa's manufacturing sector. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(1), Article 100226. <https://doi.org/10.1016/j.joitmc.2024.100226>

- Nigussie, E., Olwal, T., Musumba, G., Tegegne, T., Lemma, A., & Mekuria, F. (2020). IoT-based irrigation management for smallholder farmers in rural sub-Saharan Africa. *Procedia Computer Science*, 177, 86–93. <https://doi.org/10.1016/j.procs.2020.10.015>
- Odhiambo, K. O., Iro Ong'or, B. T., & Kanda, E. K. (2021). Optimization of rainwater harvesting system design for smallholder irrigation farmers in Kenya: A review. *AQUA – Water Infrastructure, Ecosystems and Society*, 70(4), 483–492. <https://doi.org/10.2166/aqua.2021.087>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, Article 71. <https://doi.org/10.1136/bmj.n71>
- Papadimitriou, I., Gialampoukidis, I., Vrochidis, S., & Kompatsiaris, I. (2024). AI methods in materials design, discovery and manufacturing: A review. *Computational Materials Science*, 235, Article 112793. <https://doi.org/10.1016/j.commatsci.2024.112793>
- Pegels, A. (2010). Renewable energy in South Africa: Potentials, barriers and options for support. *Energy policy*, 38(9), 4945–4954. <https://doi.org/10.1016/j.enpol.2010.03.077>
- Peter, O., Pradhan, A., & Mbohwa, C. (2023). Industry 4.0 concepts within the sub-Saharan African SME manufacturing sector. *Procedia Computer Science*, 217, 846–855. <https://doi.org/10.1016/j.procs.2022.12.281>
- Philbeck, T., & Davis, N. (2018). The fourth industrial revolution: Shaping a new era. *Journal of International Affairs*, 72(1), 17–22. <https://www.jstor.org/stable/26588339>
- Pieterse, H. (2021). The cyber threat landscape in South Africa: A 10-year review. *The African Journal of Information and Communication*, 28. <https://doi.org/10.23962/10539/32213>
- Pypenko, I. S., & Melnyk, Yu. B. (2021). Principles of digitalisation of the state economy. *International Journal of Education and Science*, 4(1), 42–50. <https://doi.org/10.26697/ijes.2021.1.5>
- Rekunenko, I., Kobushko, I., Dzydzyguri, O., Balahurovska, I., Yurynets, O., & Zhuk, O. (2025). The use of artificial intelligence in public administration: Bibliometric analysis. *Problems and Perspectives in Management*, 23(1), 209–224. [https://doi.org/10.21511/ppm.23\(1\).2025.16](https://doi.org/10.21511/ppm.23(1).2025.16)
- Ukoba, K., Jen, T.-C., & Yusuf, A. A. (2025). Transformation of South Africa's energy landscape: Policy implications, opportunities, and technological

innovations in the fourth industrial revolution. *Energy Strategy Reviews*, 59, Article 101752. <https://doi.org/10.1016/j.esr.2025.101752>

Wanyama, J., Bwambale, E., Kiraga, S., Katimbo, A., Nakawuka, P., Kabenge, I., & Oluk, I. (2024). A systematic review of fourth industrial revolution technologies in smart irrigation: Constraints, opportunities, and future prospects for sub-Saharan Africa. *Smart Agricultural Technology*, 7, Article 100412. <https://doi.org/10.1016/j.atech.2024.100412>

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, 26(2). <http://www.jstor.org/stable/4132319>

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