

THE CHALLENGES IN IMPLEMENTING FOURTH INDUSTRIAL REVOLUTION TECHNOLOGIES IN THE MANAGEMENT OF SMALL AND MEDIUM SIZE ENTERPRISES

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ABSTRACT

The implementation of Fourth Industrial Revolution (4IR) technologies in the management of Small and Medium-Sized Enterprises (SMEs) is associated with numerous challenges. In line with this development, the importance of 4IR technologies in improving SME management to enhance productivity and efficiency has grown considerably. However, the integration of these technologies into SME management faces numerous challenges. This research explores the challenges hindering the adoption of 4IR technologies in the management of SMEs in South Africa. The study utilizes a systematic review of existing literature, gathers data through a questionnaire-based survey, and conducts both descriptive and inferential analyses to interpret the findings. The results indicate that the main challenges to 4IR technology adoption include an absence of pertinent skills, insufficient training opportunities, high technology costs, and negative perceptions among industry professionals, such as concerns about job displacement. These findings are significant for SME owners and managers, offering insights to help them make informed decisions, raise awareness, and promote the integration of 4IR technologies into their business operations.

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1. INTRODUCTION

The fourth industrial revolution (4IR) is rapidly changing the way the global economy operates with new technologies, such as automation, artificial intelligence (AI), big data analytics and the Internet of Things (IoT). Such technologies could facilitate enhancing the productivity, efficiency, and competitive position of small- and medium-sized enterprises (SMEs) but have proven difficult to implement. Central to each of these has been the dearth of digital skills (read, poor technological knowledge) within workers and business alike, including automation, cybersecurity and data analytics skills. Limited access to formal training programmes exacerbates this skills gap, leading to

inefficient use of technological systems and slow digital transformation processes (Shibiti et al., 2023). Moreover, the high cost of procuring 4IR technologies and their maintenance, which encompasses infrastructure, software, and cybersecurity systems, puts significant financial pressure on SMEs, particularly in areas where financing is limited (Kothapalli, 2022). In addition to financial and technical constraints, resistance to change and negative perceptions of 4IR technologies also hinder the adoption of 4IR technologies by SMEs. Employees are worried that automation will take their jobs and SME owners worry about cyber-attacks, system reliability, integration issues, and potential poor returns on investment (Olaitan & Mapanga, 2024). Lack of organised support processes and training programmes

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also impair the ability of SMEs to generate good implementation plans, thus hindering their potential to leverage digital innovations (Bayo, 2019). As a result, the majority of SMEs today find it difficult to compete with competitors and to survive in a more digitised economic environment. To meet these challenges, there is a need for focused interventions on talent development programmes, financial support mechanisms and policies to encourage adopting 4IR in SME management and operations through innovative technologies (Shibiti et al., 2023).

This study aims to identify the major challenges hindering the implementation of 4IR technologies in SME management and propose practical solutions to address them. It looks into the difficulties South African SMEs have using these technologies, emphasising issues such as low skill levels, a lack of training materials, exorbitant prices, and unfavourable industry opinions. A thorough review of existing literature was carried out to identify the key factors required for successful integration of 4IR technologies. This review offers valuable insights into the critical skills, tools, and strategies needed for SMEs to effectively adopt and implement 4IR innovations. In order to comprehend how other economies and companies have handled comparable difficulties, the study also looked at case studies and global best practices. The report makes recommendations for strategic interventions to assist SMEs in using 4IR technologies based on literature analysis and empirical data. These consist of focused skill development initiatives, government-industry partnerships to improve training capabilities, financial support networks to lower costs, and awareness campaigns to overcome change aversion. The study highlights how crucial a well-organised roadmap is to the gradual and sustainable adoption of 4IR technologies by SMEs. Although the report focusses on SMEs in South Africa, other developing economies dealing with comparable financial and technology challenges can benefit from its recommendations. In an increasingly digitalised global market, SMEs may improve efficiency, competitiveness, and long-term sustainability by removing these obstacles.

2. LITERATURE REVIEW

The Fourth Industrial Revolution has created significant opportunities for small and medium-sized entities - SMEs in technology. Today these involve automation technology, artificial intelligence software, big data analytics, digital platforms and more. By introducing these new technologies, the operations or management practices of SMEs will also improve: for example, through innovative thinking and decision making; better performance operations; etc. However, despite the opportunities presented by 4IR technology, many in small and medium enterprises still face major problems in their actual practice of implementation and the manner an enterprise moves. Prior research highlights some of

the significant barriers to digital transformation such as low levels of technical and digital skills, limited training capacity, poor adoption, costly implementation, and negative views about digital transformation among professionals in industry. These barriers are of particular importance in countries such as South Africa and other developing economies, where SMEs often encounter financial, institutional and human resource limitations. Skills shortages and limited access to dedicated training programs decrease workforce readiness and hamper the effective use of cutting-edge advanced technologies. The high up-front investment and ongoing maintenance costs of 4IR technologies also put significant financial pressure on many SMEs, making it difficult for most businesses to adopt. Fear of the technical complexity, high exposure to cybersecurity threats, job loss with no returns on investment as well as an uncertain business case for investment also prevent acceptance among business owners and employees. As a result, targeted measures for better digital skills transfer, increasing training capacity, support mechanisms and long run knowledge of digital transformation for SME sustainability and competitiveness are necessary.

The successful execution of 4IR technologies in small and medium-sized enterprises (SMEs) would have very little success without a trained, digitally skilled workforce. The presence of employees who have limited technical experience in data analytics, cybersecurity, cloud computing, automation and programming contributes to the challenges faced by many SMEs in making the most of advanced technologies like artificial intelligence (AI), the Internet of Things (IoT) and big data analytics (Sharabati et al., 2024). Alongside technical capabilities managerial and strategic competencies are necessary to ensure that organisational goals and operational demands are met on the technological front. These challenges require selective intervention like government-driven digital literacy programmes, vocational training initiatives, and industrial-teacher links at both economic and education levels to improve the competitiveness of SMEs and narrow skills gaps (Peretz-Andersson et al., 2024). Moreover, the best way to integrate 4IR technologies efficiently is through structured programmes of training that enhance technical and managerial abilities. Nonetheless, as many SMEs are hampered by financial constraints and are not equipped to access specific training facilities, mechanisms for support, such as mentorship programmes, subsidised training and accessible learning centres, become essential (Achieng & Malatji, 2022).

Another key barrier for SMEs in adopting 4IR technologies is high implementation costs; businesses face issues around the cost of investment in infrastructure, software, cybersecurity systems, integration activities and staff training to prepare for digital transformation. The fear of uncertain returns on investment also deters the adoption of these technologies for many SMEs (Serumaga-Zake & van der Poll, 2021). Governments and financial institutions can respond by

making grants, subsidies, and low-interest loans available, while cloud-based systems and Software-as-a-Service (SaaS) models provide much more cost-effective alternatives to conventional technology investments to alleviate financial pressure (Munongo & Pooe, 2022). Furthermore, perceptions of industry professionals also play a significant role in adoption decisions since resistance to change is often due to perceptions of job displacement, cybersecurity risks, and implementation complexity (Adegbite & Govender, 2021). Such limited capacity for digital risk management increases cybersecurity concerns of SMEs (Adelowotan, 2021). Thus, an awareness campaign, the launching of a targeted training programme, and government-backed risk management initiatives must be established to boost a positive outlook toward 4IR technologies and foster a culture of innovation and digital transformation among SMEs.

3. METHODOLOGY

A multifaceted research methodology was employed to investigate issues relating to incorporating 4IR technologies in SME management. The study utilized a well-conducted literature review to assess existing studies and contributions in the area. Professional sources, especially Web of Science and Google Scholar, known for their wide collection of peer-reviewed journal articles, were systematically identified. According to Qi et al. (2021), synthesising findings from numerous studies is important for understanding the state of research of a specific field. This approach allowed the study to extract the relevant theories, empirical reports and academic debates on the implementation of 4IR technologies in SME management. A systematic search strategy to search keywords related to 4IR technology adoption and SME management challenges was applied to inform the literature selection process. In the first step, 150 articles within various databases were identified through the search. However, rigorous inclusion and exclusion criteria based on relevance, and credibility of publications were used to control the quality and relevance of each study to the research aims. We excluded duplicates to facilitate the review process, and after a comprehensive screen and eligibility process, the following 100 articles were identified for detailed analysis. The literature included was essential in providing relevant information concerning the technological, financial, and human capital issues facing SMEs in adopting 4IR technologies.

A quantitative survey is used to gather data from respondents about the challenges related to implementing 4IR technologies in SMEs. The structured questionnaire was used to provide insights on the perceptions of the participants on the adoption and integration of 4IR in SME management. To determine the extent to which respondents agreed or disagreed with statements associated with 4IR, they used a 5-point Likert scale as the appropriate measurement instrument. We developed

the questionnaire through a comprehensive literature study to ensure that it is congruent with the existing literature on problems in implementing 4IR in South Africa. The instrument was written in clear and easy-to-read forms: closed-ended, multiple-choice questions. According to Churchill Jr. and McLaughlin (2001), a face validity test was performed to ensure that the questionnaire was adequate to answer the intended research questions. The questionnaire consisted of two sections to allow complete data collection. Section A addressed respondents' biographical and demographic information, whereas Section B explored the particular barriers faced by SMEs in adopting 4IR technologies in their business operations. Data were collected based on a 5-point Likert scale from 1 = Strongly Disagree to 5 = Strongly Agree for responses derived from the literature review. Through this approach, the study was able to quantify respondents' perceptions and produce a data-driven assessment of the most significant obstacles in terms of technological development and digital transformation impact in SME management.

The study population: SME owners and managers in North West Province industrial parks were selected using a non-probability convenience sampling method to capture the overall national profile. Questionnaires were administered to 110 SME owners and managers across identified industrial parks in order to collect data. This selection size was deemed suitable for the study's nature, as, as mentioned in Smallwood and Emuze (2016), they carried out an example of a study also involving such kind of sample with 92 participants. This sample size would be consistent with common research practice which provides practical feasibility and reliability of results. Of 110 questionnaires administered, 88 responded and 80% were returned to the survey. This high response rate enhanced the validity and reliability of findings of the study. According to Wu et al. (2022), low response rates below 40% could raise validity concerns; however, responses at least 60% are typically considered valid in a research setting. Since the study surpassed this recommended cut off value, the data were deemed robust and adequate for an analysis. Subsequent to data collection, the completeness and accuracy of the finished questionnaires were screened which allowed for statistical analysis by the Statistical Package for the Social Sciences. This process, in turn, facilitated extensive statistical assessment and the ability of the study to provide credible conclusions to the challenges of adopting 4IR technologies in the field of SME management.

4. ANALYSIS OF RESULTS

This study used a multifaceted research approach, combining systematic literature review with an empirical investigation to thoroughly examine the difficulties in incorporating 4IR technologies into the management of SMEs. The literature evaluation entailed a thorough analysis of prior research from reliable databases,

identifying significant obstacles to the implementation of 4IR, and synthesising earlier findings to build a solid theoretical foundation. This offered insightful information about prevalent patterns, roadblocks, and possible solutions for implementation issues. An empirical study was carried out using structured questionnaires aimed at SME owners and managers to evaluate their viewpoints, experiences, and difficulties with 4IR implementation in order to supplement the literature review. The empirical analysis provided statistical evidence of major barriers to the implementation of 4IR machineries in SME operations. Through the integration of theoretical insights and empirical data, the study offers a comprehensive knowledge of the challenges SMEs encounter while implementing 4IR technology.

4.1. Results from Secondary Data

This segment offers an analysis of the findings from the methodical literature assessment, highlighting the various 4IR technologies that can be utilized to optimize the management of SMEs. It investigates the ways in which new technologies might boost productivity, simplify corporate procedures, and stimulate creativity in SMEs. The section also discusses the difficulties in successfully implementing 4IR technologies in SME management are also covered in this section. In a nutshell, this section attempts to give a broad overview of the challenges related to 4IR implementation in SMEs and offer workable solutions for guaranteeing a seamless

transition into the digital economy by combining insights from the body of existing research.

4.1.1. Available 4IR Technologies for SMEs

One of the biggest problems facing the business community in most nations such as South Africa is the poor application of 4IR technologies in the management of SMEs. Improving operational effectiveness, competitiveness, and long-term sustainability all depend on resolving this challenge. According to Olaitan and Mapanga (2024), since 4IR technologies enable automation, data-driven decision-making, and real-time operational monitoring, their successful integration is essential to enhancing SME management. The 4IR encompasses a range of advanced technologies that seamlessly integrate from the initial planning phase to the real-time management of business operations. The 4IR encompasses a range of advanced technologies that collaborate seamlessly, from the initial planning phase to the continuous real-time management of business operations. A thorough analysis of the literature has revealed a number of important 4IR technologies with important business-related uses. By integrating 4IR technologies into their business operations, SMEs can enhance productivity, reduce costs, improve customer experiences, and stay competitive in an increasingly digital economy. Here are specific types of 4IR technologies that are applicable to SMEs, along with descriptions of how each can be integrated into business operations and the sources of the information as depicted in table 1.

Table 1. The Available 4IR Technologies for SMEs

Technologies	Role	Source
Artificial Intelligence (AI)	AI helps SMEs to enhance customer experiences, streamline operations, and automate decision-making processes. Companies can utilise machine learning algorithms for targeted marketing, predictive analytics for demand forecasting, and AI-powered chatbots for customer support. Automation driven by AI can also improve fraud detection and inventory management	Chaitanya et al. (2023); 'Anozie et al. (2024).
Internet of Things (IoT)	In order to exchange data in real time, IoT entails connecting equipment and devices to the internet. IoT-enabled sensors can be used by SMEs to maintain inventory levels, monitor supply chains, and enhance predictive maintenance for equipment. IoT can reduce operational inefficiencies in retail by assisting with automated stock replenishment and smart shelving	Sahara and Aamer (2022); Taj et al. (2023)
Big Data and Analytics	By using data analytics, SMEs can improve customer segmentation, make well-informed business decisions, and create focused marketing strategies. Real-time data analysis also aids in identifying inefficiencies and optimising resource allocation. Big data analytics enables SMEs to process vast amounts of data to obtain insights into customer behaviour, market trends, and operational performance	Mikalef et al. (2019); Cadden et al. (2023).
Cloud Computing	Cloud computing eliminates the need for costly on-premises infrastructure by allowing SMEs to access computer resources, software, and storage via the internet. Companies may increase cooperation, boost scalability, and guarantee data protection by utilising cloud-based accounting software, CRM platforms, and enterprise resource planning (ERP) solutions	Attaran (2017); Al-Sharafi et al. (2023).

Blockchain Technology	Blockchain guarantees business transactions are efficient, secure, and transparent. Blockchain can be used by SMEs for supply chain management, smart contracts, and safe financial transactions. It offers a decentralised, impenetrable ledger that lowers the risk of fraud while boosting stakeholder trust	Ioannou and Demirel (2022); Agrawal et al. (2023).
Robotics and Automation	SMEs in manufacturing can use robotic arms for assembly lines, and companies in logistics and warehousing can use automated sorting and packing systems to increase productivity. Automation through robotics can streamline production processes and repetitive tasks, improving efficiency and lowering labour costs	Dhaliwal (2020); Sodiya et al. (2024).
3D Printing (Additive Manufacturing)	SMEs can quickly develop and produce customised items using 3D printing with minimal material waste. By using 3D printing to produce prototypes, replacement parts, and customised goods, businesses in sectors such as fashion, healthcare, and automotive can save production costs and lead times	Oyinlola et al. (2023); Milliken et al. (2024).
Cybersecurity Technologies	SMEs need to put strong cybersecurity safeguards in place to safeguard sensitive data and digital assets as their reliance on digital solutions grows. Businesses are protected from cyber threats by firewalls, encryption, biometric authentication, and AI-driven threat detection systems, which also guarantee data integrity and regulatory compliance	Benjamin et al. (2024); Papathanasiou et al. (2024).
Augmented Reality (AR) and Virtual Reality (VR)	AR and VR technology improve product visualisation, personnel training, and customer interaction. While construction and real estate companies can utilise VR to provide immersive property tours, retail SMEs can employ AR to create virtual try-on experiences. Furthermore, AR-based training initiatives assist staff members in becoming more proficient in technical duties.	Enyejo et al. (2024); Billano et al. (2024)
Edge Computing	By processing data closer to the source, edge computing helps SMEs make better decisions in real time by lowering latency. By using edge computing to analyse and act on data locally rather than depending on centralised cloud servers, businesses employing IoT devices may increase productivity and response times	Kelly (2024); Simuni et al. (2024).

Through the adoption of 4IR technologies, SMEs can improve customer service, operational efficiency, reduce costs and even make better decisions. AI enables predictive analytics for demand forecasting, AI-powered chatbots to help customers with support, machine learning to provide personalised experiences and targeted marketing, fraud detection and inventory management automation among other uses. The Internet of Things (IoT) is changing the pattern of work for SMEs by connecting products and resources together in a real-time way to facilitate data transmission, predictive maintenance and monitoring for stock movements. Smart shelving and automated stock replenishing are other ways in which inefficiencies in retail management are being diminished. Cloud computing and data analytics offer an inexpensive way to access computing resources, software and secure data storage, and cloud-based accounting systems, customer relationship management (CRM) and enterprise resource planning (ERP) platforms provide enhanced collaboration, scalability and operational efficiency. Also, big data analytics contributes to better customer segmentation, targeted

marketing and business performance. Blockchain reduces the risk of fraud, increases transparency and increases trust in finance, supply chains, and smart contracts through the facilitation of transparent, secure, and decentralised transactions and improves SME operations. Through automation and robotics, the productivity of mass production and distribution in manufacturing and logistics is enhanced through robotic arms and automated sorting systems, and 3D printing is a vehicle for SMEs to produce prototypes and customised products with reduced costs and reduced waste. Cybersecurity software and technologies like encryption, firewalls, biometric authentication, AI-enabled threat detection keep sensitive data secure through the implementation of technology and compliance. What’s more, AR, VR and edge computing: augmented reality, virtual reality, edge computing all accelerate customer engagement, training of employees and decision making, driving SMEs to stay ahead in the digital economy – competitive, innovative and sustainable.

4.1.2. Challenges of 4IR Technologies Implementation in SMEs

The effective integration and utilization of 4IR technologies in SME management face several challenges. The primary barriers include insufficient relevant skills among employees, limited training resources to equip SMEs with essential technological competencies, and the high costs associated with acquiring and maintaining 4IR technologies. Furthermore, the implementation is often impeded by views and opinions of industry professionals regarding the adoption of 4IR technologies which are scepticism, resistance to change, and concerns about job displacement. These problems must be fixed if SMEs are to properly employ 4IR technology, boost productivity, and stay competitive in a shifting digital economy.

Insufficient Relevant Skills for the Adoption of 4IR Technologies: A major challenge to the adoption of 4IR technologies in SME management is the shortage of qualified personnel. Many SMEs struggle to find employees with the specialized expertise required to operate advanced digital tools such as artificial intelligence (AI), big data analytics, blockchain, cloud computing, and the Internet of Things. Technology adoption is further hampered by the frequent lack of digital literacy among SME owners and managers. The skills gap is made worse by inability of SMEs owners and managers to invest in staff training and upskilling due to a lack of funding (Shibiti et al., 2023). Consequently, SMEs run the risk of falling behind in the digital economy without adequate personnel development, underscoring the pressing need for 4IR technology education and capacity building.

Limited Training Capacities for the Integration of 4IR Technologies: The absence of sufficient training capabilities is a major obstacle to the use of 4IR technologies in SME management. Traditional institutions have not yet kept up with the rapid improvements in technology, and many SMEs have limited access to specialised training programs. Employee growth is further hampered by the high expense of professional training and the dearth of industry-sponsored upskilling programs. SMEs find it difficult to successfully use automation, cloud computing, big data, and AI without formal training (Olaitan & Mapanga, 2024). As a result, to solve this problem, academic institutions, legislators, and business executives must work together to develop scalable and reasonably priced training programs that prepare SMEs for the digital economy.

High Cost of 4IR Technology Adoption: For SMEs, which frequently have tight budgets, the substantial financial outlay necessary for the deployment of 4IR technology presents a serious obstacle. Financial obstacles to digital transformation are brought about by the price of purchasing AI, big data, IoT, and automation systems as well as by maintenance, update, cybersecurity, and staff training costs. SMEs find it difficult to find capital or investors for technology-driven expansion, in contrast to huge enterprises (Kothapalli,

2022). Therefore, in order to address these cost-related issues, government incentives, industry partnerships, and easily accessible financing options, like grants or low-interest loans, are essential. Many SMEs run the danger of lagging behind in terms of operational effectiveness and digital competitiveness without financial support.

Perceptions of Industry Professionals on 4IR Adoption: The successful implementation of 4IR technologies in SME management relies heavily on the insights and perspectives of industry professionals. Uncertainty, scepticism, or concerns about job displacement and operational disruptions are the main reasons why many managers, employees, and business owners oppose new technologies. Adoption of 4IR is seen as complicated or unnecessary by some, and deployment is further discouraged by worries about data security, system dependability, and return on investment. Adoption is slowed by misconceptions caused by a lack of exposure to successful case studies and insufficient training (Bayo, 2019). Hence, campaigns to raise awareness, practical success stories, and practical training are necessary to overcome these obstacles and instil trust in the advantages of 4IR technologies for productivity, creativity, and competitiveness.

4.2. Empirical Findings

This section explores the primary barriers to adopting 4IR technology in the management of South African SMEs. It highlights challenges such as a shortage of skilled workers, limited training resources, the high cost of adopting new technologies, and industry professionals' perspectives on digital transformation. These issues hinder the successful integration of advanced technologies like automation, cloud computing, big data analytics, and artificial intelligence (AI) into SME operations. The analysis of these challenges provides valuable insights into the difficulties SMEs face when implementing 4IR technologies in their business management processes.

4.2.1. Challenges of 4IR Technologies Implementation in SMEs

This section presents the findings from both descriptive and inferential analyses regarding the challenges in integrating 4IR technologies into SME management. The descriptive study offers a thorough summary of the main obstacles that SMEs must overcome. The inferential analysis, on the other hand, looks at the statistical connections between these difficulties and different business attributes, providing a better understanding of the ways in which various elements affect the adoption of 4IR. This part offers a thorough grasp of the barriers preventing the incorporation of 4IR technologies in SME management by integrating the two analytical methodologies.

4.2.1.1. Descriptive Results on the Implementation Challenges

The descriptive analysis reveals that the high cost of technologies is the most critical challenge in implementing 4IR in SME management. This facet is graded first, with a mean score of 3.95 and a standard deviation value of 1.20; fear of job displacement is rated second where MS is 3.92 and SD is 1.15. A lack of suitable abilities is rated third where MS is 3.72 and SD is 1.18, the high cost of adoption is graded fourth where MS is 3.58 and SD is 1.21); the lack of training proficiencies is rated fifth where MS is 3.57 and SD is 1.34. On the other

hand, the challenges considered least significant are the lack of access to wireless broadband, ranked fourteenth with a mean score (MS) of 3.16 and a standard deviation (SD) of 1.27; lack of interest, ranked fifteenth with an MS of 3.07 and an SD of 1.30; and insufficient electricity, ranked sixteenth with an MS of 2.84 and an SD of 1.49. This means that certain challenges may pose a greater risk than others for the adoption of 4IR technology. Table 2 illustrates a comprehensive summary of the statistical findings, providing a thorough representation of the analyzed data in this study.

Table 2. Implementing challenges associated with the implementation of 4IR technologies

Challenges of Adopting 4IR Technologies by SMEs	\bar{x}	σX	R
High cost of technologies	3.95	1.203	1
Fear of job displacement	3.92	1.147	2
Insufficient skills	3.72	1.184	3
Insufficient financial resources for adoption	3.58	1.210	4
Limited availability of training facilities	3.57	1.335	5
Preference for old-style techniques	3.56	1.303	6
Lack of client funding	3.55	1.372	7
Resistance to change	3.55	1.330	7
Inadequate financial resources	3.49	1.330	8
Insufficient skilled technical support	3.49	1.268	8
Inadequate innovation	3.44	1.353	9
Absence of client demand	3.43	1.258	10
Misalignment of labour	3.38	1.187	11
Project size	3.35	1.269	12
Limited availability of experts	3.35	1.269	12
Inadequate education	3.26	1.280	13
Limited access to wireless broadband	3.16	1.268	14
Lack of awareness	3.07	1.302	15
Inadequate electrical energy supply	2.84	1.485	16

\bar{x} = Mean item score; σX = Standard deviation; R = Rank.

4.2.1.2. Factor Analysis Results (Inferential Analysis) on challenges of implementing 4IR technologies

An exploratory factor analysis (EFA) was performed to identify the challenges involved in implementing 4IR technologies in SME management. A total of 19 variables were considered, and principal component analysis (PCA) was used to examine 15 of these variables with the aid of Statistical Package for the Social Sciences (SPSS) software, version 26. Before conducting the PCA, the data's suitability for factor analysis was assessed. The correlation matrix analysis showed that several variables had coefficients greater than 0.30, validating their appropriateness for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.80, exceeding the recommended minimum value of 0.6. Furthermore, Bartlett's Test of Sphericity was statistically significant, with a value of 0.000, confirming the dataset's appropriateness for factor analysis.

The findings regarding the challenges faced by SME owners and managers in implementing 4IR technologies, along with their corresponding eigenvalues, are presented in Table 3. Following Kaiser's criterion, which retains components with eigenvalues greater than one, four primary challenges were identified. These challenges had eigenvalues of 6.10, 1.97, 1.72, and 1.43, explaining 32.08%, 10.39%, 9.03%, and 7.51% of the variance, respectively. This means that the first factor accounted for 32.08% of the variance related to the challenges, the second explained 10.39%, the third covered 9.03%, and the fourth contributed 7.51%. Collectively, these four factors explained a cumulative variance of 59.02%, highlighting their significance among the 19 identified obstacles.

It is crucial to draw attention to the turning point that follows the fourth component of the difficulties SMEs have when implementing the 4IR technologies into business operations. The most important components are

indicated by the sharp incline, and the remaining variables with eigenvalues smaller than one are represented by the gradual decrease. The four most prominent components were thus kept for further

examination. This selection process resulted in the formulation of the pattern matrix, which is thoroughly detailed in Table 3.

Table 3. Pattern Matrix.

Conditions	Components			
	1	2	3	4
Inadequate technical sustenance	0.832			
Shortage of experts	0.829			
Limited training capacity	0.650			
Insufficient relevant skills	0.624			
Inadequate customer demand	0.599			
Lack of awareness of adoption	0.540			
Preference for old-style techniques	0.403			
High cost of technology implementation		0.746		
Resistance to change		0.644		
Deficiency in innovation		0.522		
Inconsistent electrical energy supply			0.452	
Lack of funding from customers			0.807	
Insufficient budget for adoption			0.703	
Lack of cost to adopt			0.601	
Project size constraints			0.600	
Inadequate education and awareness				0.795
Limited availability of experts				0.731
Concerns over job displacement				0.656
Limited access to wireless broadband				0.612

The results of the factor analysis identified four principal components, with the associated percentages indicating their respective component loadings.

As presented in table 3, the factor analysis identified four key components influencing the implementation of 4IR technologies in SMEs, each associated with distinct challenges.

Component 1: This section comprises seven factors identified as human-related obstacles to the adoption of 4IR technologies, as described by Serumaga-Zake and van der Poll (2021). These barriers include inadequate technical support (83.20%), shortage of specialists (82.90%), lack of training resources (65.00%), insufficient relevant skills (62.40%), absence of client demand (54.00%), lack of interest (64.40%), and a preference for traditional methods (40.30%). These challenges highlight the crucial importance of human resource capacity for the successful integration of 4IR technologies into SME management.

Component 2: As presented in Table 4, this component includes three items associated with management-related challenges, as identified by Serumaga-Zake and van der Poll (2021). These challenges encompass the perception that 4IR technologies are excessively costly (74.60%), resistance to change (64.40%), and a deficiency in innovation (52.20%). These management-related barriers suggest that leadership attitudes and decision-making significantly impact the willingness of SMEs to embrace digital transformation.

Component 3: This component comprises five elements related to cost-associated challenges, as identified by Serumaga-Zake and van der Poll (2021). These financial challenges include inadequate electricity supply (45.20%), lack of financial resources (80.70%), insufficient client funding (70.30%), inability to afford adoption costs (60.10%), and limitations due to project size (60.00%). These findings underscore the substantial financial strain SMEs face in acquiring and maintaining 4IR technologies.

Component 4: This component encompasses four factors associated with standardization challenges in 4IR implementation, as proposed by Serumaga-Zake and van der Poll (2021). These challenges consist of insufficient education (79.50%), misalignment between labor supply and demand (73.10%), fear of job displacement (65.60%), and restricted access to wireless broadband (61.20%). These findings underscore the need for structured educational and workforce development initiatives to equip SME labor forces with the necessary technological skills required in the digital economy. Additionally, the standardization challenges suggest the importance of strategic policy interventions to facilitate a seamless transition to 4IR technologies within SMEs.

5. DISCUSSION

This section explores the barriers South African SMEs encounter when they try to utilize 4IR technologies and

how these barriers relate to the way they do their business. The discussion is based on the findings of the factor and descriptive analyses presented above and is also interpreted relative to the published literature. The results found in this study confirm that SMEs have barriers to 4IR adoption which align with previous studies, but the importance and ranking vary and thus the barriers differ across firms according to their sectors and geographic contexts. Therefore, there is a need for context-specific approaches to facilitate 4IR integration in SMEs. The literature review highlighted the prominent challenges such as high costs of 4IR technologies, fear of job losses, lack of skills, limited training capacity, shortage of specialists, and poor education followed by inadequate broadband connectivity, low adoption motivation, and insufficient electricity supply. The descriptive analysis suggested that cost constraints, skills shortages, job security concerns, and training limitations were mostly highlighted as barriers in the discussions. Factor analysis also classified these challenges into 4 main components. The first component emphasized human resource constraints especially in skills and training capacity, while low motivation and specialist availability were less significant. The second one highlighted high technological costs as the main managerial barrier. The third element confirmed lack of financial and infrastructural resources with cost foremost and lack of access to electricity, education, and broadband less severe. The fourth element highlighted standardisation problems, where concern for job losses became the primary issue. As a whole, these findings add systematically to our understanding of the main barriers toward adoption of 4IR in SMEs.

The study reveals that insufficient skills and a lack of training resources pose the largest risks to implementation of 4IR technologies in the management process of SMEs. Mahbob et al. (2024) emphasize that professionals are reluctant to adopt digital training and are resistive to change. Adoption is further hampered by inadequate technical knowledge and a lack of strategies for capacity training. According to Brunello and Wruuck (2021), e-government projects encounter comparable difficulties because of a shortage of qualified staff. The lack of qualified experts and technicians makes implementation challenging because these technologies are still relatively new in South Africa. In contrast to Mahachi (2020) who contended that SME owners frequently view 4IR technologies as impracticable, which results in a lack of interest, the study indicated that lack of interest and the unavailability of professionals are less major problems. The results of this study are called into question by Kariem (2020), who added that many SMEs have difficulty locating the technical staff required for implementation. Mahachi (2020) affirms that small business enterprises are reluctant to adopt new ideas, rejecting 4IR technologies as being too expensive instead of coming up with ways to get around implementation obstacles. Progress is still hampered by this unwillingness to change as well as false beliefs about the price of technology.

In SME management, financial constraints were reported as a significant obstacle to the implementation of 4IR technologies, as the lack of funding was one of the most significant risks for implementation. Shibiti et al. contend that SMEs, with limited assets and constrained managerial resources, may be less financially equipped to make use of 4IR technologies in their business. But many small businesses lack the necessary capital to make the leap to digital transformation and pay the associated costs. Unlike Mhlongo and Thomas (2024), who highlighted the detrimental effects of frequent power cuts on business activity, this investigation revealed insufficient electricity supply to be seen as a less critical challenge to 4IR implementation by SMEs, which is nonetheless another structural obstacle towards industrialisation in South Africa. Job security concerns have also been cited as a key barrier especially in a context of high unemployment. On the other hand, SME managers and employees are generally reluctant to embrace 4IR due to fears in automation and advancement of technology leading to the displacement of job. These results are consistent with Gaspar et al. (2019) who noted limited access to wireless broadband and illiteracy as often considered low-risk barriers in certain contexts. However, Afzal et al. (2023) argue that broadband access is a significant challenge due to the high connectivity needs of modern technologies. Therefore, the awareness-raising, training-focused programmes, inclusion of 4IR in education curricula, promotion of professional development programmes, and incentives from the government are important steps to assist SMEs and their digital transformation and competitiveness in the emerging digital economy.

6. CONCLUSIONS

The SME sector plays a vital role in the economic development of South Africa in terms of creating employment opportunities, contributing to GDP, and poverty alleviation. However, there are several challenges to the integration of the 4IR technologies into SME management, such as a shortage of qualified staff, poor training initiatives, expensive implementation expenses, and the negative perception of industry professionals. The potential efficiency and productivity benefits that 4IR technology could provide are hampered by these issues. Although the emphasis of this study is South Africa, many underdeveloped and developing nations throughout the world face similar obstacles to the adoption of 4IR technologies. Many SMEs habitually rely on government assistance, and their limited finances and size further limit their capacity to implement cutting-edge technologies. However, policymakers, business executives, and academic institutions must work together to address these problems and create plans that make it easier for small business enterprises to incorporate 4IR tools into their daily operations. Beyond the issue of low knowledge, which has been noted in the literature, SMEs have financial and structural barriers that hinder the

seamless integration of 4IR technologies. Many small business enterprises depend on government interventions for support since they lack the financial means and authority to invest in digital transformation. This emphasises how urgently governments in South Africa and around the world must review laws and regulations to foster an atmosphere that supports the use of 4IR in SME management. To assist companies in their digital

transformation, workable solutions including training programs, financial incentives, and customised regulatory changes ought to be implemented. In order to ensure long-term sustainability and competitiveness in the digital age, policymakers and SME owners may both reduce the obstacles to 4IR integration by putting proactive strategies into place.

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Evaluating the Quality and Process Capability of Smartphone Navigation Systems: A Comparative Study of Travel Time Prediction Performance