

Bridging the Digital Divide: AI Adoption for SMME Sustainability in Resource-Constrained Regions

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Abstract

Small, Medium, and Micro Enterprises (SMMEs) are essential to economic development, particularly in resource-constrained settings like South Africa's Northern Cape. This study explores the potential of artificial intelligence (AI) and digital technologies in enhancing the resilience, competitiveness, and sustainability of SMMEs in the Northern Cape province of South Africa. Using a qualitative research approach and a phenomenological design, semi-structured interviews were conducted with representatives from ten SMME support agencies. Thematic analysis revealed key barriers to technology adoption, including limited digital literacy, high implementation costs, and inadequate infrastructure. Despite these challenges, the findings highlight the transformative potential of technologies such as predictive analytics for market trend forecasting, 3D printing for product customization, and AI-powered chatbots for enhancing customer engagement. These tools enable SMMEs to optimize operations, expand market access, and innovate despite resource constraints. The study bridges technology adoption theories, including the Technology Acceptance Model (TAM) and Diffusion of Innovations Theory, with the unique socio-economic dynamics of resource-constrained environments. The findings offer actionable insights for policymakers, support agencies, and SMME practitioners, emphasizing the critical need to address systemic barriers and foster an enabling environment for digital transformation.

Keywords

Artificial Intelligence (AI) Adoption, SMME Sustainability, Digital Transformation, Technology Acceptance Model (TAM), Resource-Constrained Environments

1. Introduction

Small, Medium, and Micro Enterprises (SMMEs) are the backbone of South Africa's economy, contributing significantly to job creation, economic growth, and poverty alleviation. These enterprises are particularly vital in underdeveloped regions like the Northern Cape, where opportunities for large-scale industrial development are limited. Despite their importance, SMMEs face persistent challenges that hinder their growth and sustainability. The slow adoption of artificial intelligence (AI) and digital technologies, driven by inadequate infrastructure, high costs, and a lack of digital skills, continues to impede their ability to leverage technology for competitive advantage (Rambe & Mlambo, 2014; Nyangiwe & Olatunji, 2021). Globally, AI and digital technologies have demonstrated transformative potential in improving efficiency, fostering innovation, and enhancing customer engagement. For example, industries adopting collaborative AI-human models have achieved significant gains in optimizing business operations (Wilson & Daugherty, 2018). However, uneven adoption across socio-economic and geographic contexts necessitates a region-specific exploration to identify enablers and barriers to technology adoption (Dwivedi et al., 2021).

Recent research highlights a growing recognition of AI's role in addressing systemic challenges for SMMEs, particularly in resource-constrained environments. Dwivedi et al. (2021) emphasize that AI technologies, such as predictive analytics, offer SMMEs opportunities to enhance decision-making and improve operational efficiencies. Similarly, Fourie (2022) explores digital adoption trends in South Africa, underscoring the potential of AI to bridge regional economic disparities by enabling SMMEs to access broader markets and innovate at scale. These studies reflect the global shift toward leveraging digital transformation for resilience and competitiveness while highlighting the barriers that persist, especially in rural and semi-urban areas.

The Northern Cape, South Africa's largest province by land area but the smallest by population, presents a unique socio-economic and geographic context. Characterized by vast arid regions and sparse populations, the province faces significant infrastructural deficits that exacerbate economic disparities (Stats SA, 2022). Despite these challenges, the Northern Cape has substantial potential in sectors such as mining, agriculture, and renewable energy (DTIC, 2021). Within this regional landscape, SMMEs play a crucial role in economic development, contributing to job creation, poverty alleviation, and regional growth (Fatoki, 2014). However, these enterprises face compounded challenges, including limited access to funding, inadequate digital infrastructure, and insufficient capacity-building opportunities (SEDA, 2023). These structural barriers restrict their ability to adopt advanced technologies like AI, which have the potential to revolutionize business operations.

Globally, the integration of AI into SMMEs has enabled firms to enhance operational efficiency, expand market access, and foster innovation (Chatterjee et al., 2021). Applications such as process automation, predictive analytics, and AI-

driven customer engagement tools have been widely recognized for their ability to transform business operations (Brynjolfsson & McAfee, 2017). However, in resource-constrained settings such as the Northern Cape, adoption is hindered by systemic challenges, including low levels of digital literacy, affordability issues, and unreliable internet connectivity (Rambe & Mlambo, 2014; Ndou, 2019). Recent studies emphasize that these barriers are not unique to the Northern Cape; rural and semi-urban regions globally face similar challenges, highlighting the importance of localized strategies to facilitate digital adoption (Abiodun & Adeola, 2020; Mahlangu & Steyn, 2022).

This study investigates how AI and digital technologies can address the challenges faced by SMMEs in the Northern Cape. Specifically, it seeks to answer the following question: How can AI and technology adoption improve the growth and sustainability of SMMEs in the Northern Cape? To address this, the study pursues the following objectives:

- To assess the current state of AI and technology adoption among SMMEs in the Northern Cape.
- To identify the key barriers and enablers to AI and technology adoption in the region.
- To evaluate the potential impact of AI and technology solutions on the growth and sustainability of SMMEs.
- To provide evidence-based insights to inform policy and practice, fostering the adoption of AI and digital technologies among SMMEs.

This research contributes to the growing body of literature on SMMEs and digital innovation in underdeveloped and resource-constrained settings. Studies from 2021 to 2023 have increasingly highlighted the role of digital transformation in driving economic resilience, particularly in regions with limited resources (Dwivedi et al., 2021; Fourie, 2022). By focusing on the Northern Cape, this study sheds light on a region often overlooked in broader discussions about adoption of technology. Prior research has emphasized the need for region-specific approaches that account for geographic isolation, infrastructure deficits, and local socio-economic dynamics (Chigona & Chetty, 2008; Hassan et al., 2020). The findings of this study will provide actionable insights for policymakers, support agencies, and practitioners, offering strategies to drive the digital transformation of the sector (Rambe, 2017).

Theoretically, this study bridges the gap between technology adoption frameworks, such as the Technology Acceptance Model (TAM) and the Diffusion of Innovations Theory, and their application in rural and underdeveloped regions (Davis, 1989; Rogers, 2003). These frameworks emphasize the importance of perceived usefulness, ease of use, compatibility, and trialability in driving technology adoption. Recent advancements in understanding rural technology diffusion have further highlighted the role of observable success stories and incremental adoption strategies in overcoming resistance to innovation (Dwivedi et al., 2021; Fourie, 2022).

Practically, the study empowers SMMEs by identifying strategies for leveraging AI and digital tools to overcome operational and strategic challenges. Additionally, it provides insights for policymakers and support agencies on fostering an enabling environment for technology adoption. Addressing these challenges will not only improve the competitiveness of SMMEs but also contribute to broader objectives of economic resilience and regional development in the Northern Cape (DTIC, 2021; Mahlangu & Steyn, 2022).

2. Literature Review

2.1. Global and National Contexts

Globally, SMMEs play a vital role in driving economic growth, employment, and innovation. In developed economies such as the United States, Germany, and Japan, technology adoption is deeply embedded in business practices. Artificial intelligence (AI) is widely utilized to optimize operations, enhance customer engagement, and improve decision-making. Tools such as predictive analytics, automation, and personalized marketing have empowered SMMEs to maintain competitiveness against larger enterprises, demonstrating the transformative potential of digital technologies (Brynjolfsson & McAfee, 2017). Furthermore, government policies in these economies often support digital transformation through tax incentives, accessible training programs, and public-private partnerships (Dwivedi et al., 2021). These interventions highlight the importance of systemic support in fostering technological adoption among smaller enterprises.

In contrast, emerging economies such as India, Brazil, and China show significant potential for AI adoption in SMMEs, albeit with uneven outcomes. Government-led initiatives like India's *Digital India* program have improved internet access and digital literacy, enabling SMMEs to integrate tools like e-commerce platforms and digital payment systems (Chatterjee et al., 2021). Similarly, China's focus on AI in manufacturing has supported smaller enterprises in automating production and enhancing operational efficiency. However, barriers such as limited infrastructure, high costs, and insufficient digital skills persist. For instance, in Brazil, urban SMMEs benefit from tech hubs, whereas rural businesses face infrastructural deficits and limited awareness of technological benefits, perpetuating a digital divide (Autor et al., 2020). These global trends emphasize the need for region-specific interventions to support SMMEs in resource-constrained settings.

In South Africa, SMMEs contribute approximately 60% of employment and 34% of GDP, underscoring their critical role in economic development (SEDA, 2023). Technology adoption, however, remains uneven across regions. Urban centers like Johannesburg and Cape Town enjoy better infrastructure, skilled labor, and access to funding, enabling businesses to leverage AI-driven solutions such as process automation, predictive analytics, and customer engagement tools (Rogerson & Sithole, 2021). In contrast, rural and semi-urban areas face persistent challenges, including poor digital infrastructure, high costs of AI tools, and low levels of digital literacy. Many SMMEs in these areas rely on basic digital tools

such as social media for marketing and mobile apps for communication (Mbuyisa, 2017). While government programs like those offered by the Small Enterprise Development Agency (SEDA) aim to address these disparities, their reach and alignment with rural businesses' specific needs remain limited (Rambe & Mlambo, 2014).

2.2. Regional Context: SMMEs in the Northern Cape

While literature provides valuable insights into AI adoption globally and nationally, significant gaps remain. First, much of the existing research focuses on urban and semi-urban areas with developed digital ecosystems, overlooking the unique challenges faced by rural and underdeveloped regions such as the Northern Cape. This geographic bias leaves a limited understanding of infrastructural deficits and geographic isolation shape technology adoption in these areas (Hassan et al., 2020; Fourie, 2022).

Second, there is insufficient empirical evidence on the specific AI applications most suitable for resource-constrained environments. While studies emphasize the transformative potential of AI tools like predictive analytics and chatbots (Brynjolfsson & McAfee, 2017; Dwivedi et al., 2021), they rarely address how these technologies can be adapted to the operational realities of SMMEs in underdeveloped regions. Similarly, the intersection of technology adoption theories such as the Technology Acceptance Model (TAM) and the Diffusion of Innovations Theory with the lived experiences of SMMEs remains underexplored. These frameworks often derive from research conducted in developed economies, limiting their applicability in contexts like the Northern Cape (Davis, 1989; Rogers, 2003).

Lastly, while barriers such as cost and infrastructure are well-documented, there is a lack of focus on capacity-building initiatives that address digital literacy challenges among SMME entrepreneurs and employees. Recent studies emphasize the importance of digital literacy in bridging technology adoption gaps (Mahlangu & Steyn, 2022), but practical strategies for implementing these initiatives remain underdeveloped. Addressing these gaps requires region-specific research that captures the lived realities of SMMEs and identifies actionable solutions for overcoming systemic barriers.

2.3. Critical Gaps in Literature

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3. Research Philosophy and Paradigm

This study employs a qualitative research methodology rooted in the interpretivist paradigm, aiming to explore the lived experiences of SMMEs and the support agencies that aid them in the Northern Cape province. The qualitative approach was selected to gain in-depth insight into the challenges and opportunities faced by SMMEs in adopting AI and digital technologies, particularly in a region characterized by dispersed populations and limited infrastructure. The interpretivist paradigm emphasizes understanding the subjective meanings that participants attribute to their interactions with technology and the socio-economic realities surrounding them. A qualitative approach is particularly well-suited for such exploratory research, as it enables the capture of rich, contextualized data that quantitative methods might overlook (Creswell & Poth, 2018).

The research design is cross-sectional, capturing data at a single point in time through semi-structured interviews with key stakeholders. The qualitative component forms part of a broader mixed-methods study, but this manuscript focuses exclusively on the qualitative findings. The semi-structured interview format allowed participants to elaborate on predetermined themes while introducing unique insights that reflected their organizational context and expertise. This flexibility ensured that data captured the nuanced experiences and diverse perspectives of stakeholders while maintaining alignment with the research objectives.

By involving a diverse range of support agencies, including the Small Enterprise Development Agency (SEDA), Industrial Development Corporation (IDC), Northern Cape Economic Development Agency (NCEDA), National Empowerment Fund (NEF), Vaal University of Technology, Kheis Local Municipality, and Love-life, the study ensured a comprehensive understanding of the ecosystem supporting SMMEs in the Northern Cape. These agencies were purposively selected for their direct involvement in SMME support and development, ensuring that par-

participants could provide relevant, firsthand insights into the challenges and opportunities surrounding AI and digital technology adoption.

The sample size of ten participants was determined based on the principle of data saturation, where additional interviews were unlikely to yield new themes or insights (Guest, Bunce, & Johnson, 2006). The purposive sampling strategy ensured that the selected participants had extensive knowledge and experience in supporting SMMEs, thereby enhancing the richness and relevance of the data. This approach aligns with qualitative research best practices, which prioritize the depth and quality of data over sheer sample size, particularly when exploring complex, context-specific phenomena (Patton, 2015).

Overall, the study's methodological choices were guided by the need to provide a detailed, nuanced understanding of how SMME support agencies address barriers to technology adoption, provide capacity-building initiatives, and facilitate economic resilience for SMMEs in the Northern Cape.

4. Data Collection and Instruments

This study collected qualitative data through ten semi-structured interviews with representatives from seven key SMME support agencies in the Northern Cape province. These agencies included the Small Enterprise Development Agency (SEDA), Industrial Development Corporation (IDC), Northern Cape Economic Development Agency (NCEDA), National Empowerment Fund (NEF), Vaal University of Technology (VUT), Kheis Local Municipality, and Lovelife. Their roles in providing financial, technical, and strategic support to SMMEs made them ideal participants for this research.

The interviews were conducted over four weeks, with three held via Microsoft Teams and seven conducted via telephone to accommodate logistical and geographical challenges. Participants were selected using purposive sampling to ensure expertise and direct engagement in technology adoption and business sustainability. Interviews ranged between 40 and 57 minutes, allowing for in-depth discussions on barriers to AI adoption, capacity-building initiatives, and infrastructural limitations.

To ensure consistency and focus, an interview guide was shared with participants a week in advance, outlining key themes to be discussed. All interviews were recorded with informed consent and transcribed verbatim for accuracy. This approach ensured the collection of rich and contextually relevant data, covering all five districts in the Northern Cape: Frances Baard, John Taolo Gaetsewe, ZF Mgcawu, Namakwa, and Pixley Ka Seme.

The selection of the ten SMME support agencies was strategic to ensure a diverse representation of geographic areas, sectors, and engagement in digital transformation. The selection criteria considered:

- Geographic distribution, ensuring inclusion from both urban and rural areas.
- Sectoral representation, covering industries such as retail, manufacturing, and services.
- The agency's role in AI and digital technology adoption, prioritizing those in-

volved in supporting innovation.

While this study acknowledges that the sample does not capture all SMME support agencies in the Northern Cape, the diversity of participants ensures a broad and well-rounded perspective on the challenges and opportunities surrounding AI adoption for SMMEs in the region.

5. Data Analysis

The qualitative data was analyzed using thematic analysis, providing a structured approach to identifying and interpreting patterns within the dataset. The process followed Braun and Clarke's six-phase framework, beginning with data familiarization through repeated readings of the transcripts. Atlas.ti software was used to systematically code the data, organizing it into emerging themes and subthemes. This facilitated a detailed examination of the socio-economic and infrastructural factors influencing SMME resilience and technology adoption.

Key themes identified included "Barriers to AI Adoption," "Capacity-Building Strategies," and "Infrastructure Challenges." These broad themes were further refined into subthemes, such as "digital skills shortages," "high costs of technology," and "funding limitations," reflecting the nuanced realities faced by SMMEs. The iterative refinement of themes ensured alignment with participants' narratives and the research objectives. Triangulation, achieved through the involvement of seven diverse support agencies, added depth to the findings and ensured a comprehensive understanding of the challenges and opportunities within the Northern Cape's unique socio-economic context.

6. Reliability and Validity

The study prioritized reliability and validity to ensure the credibility and robustness of the research findings. Reliability was achieved through the consistent application of the semi-structured interview guide, ensuring uniformity across the interviews while accommodating flexibility for participants to share unique insights. The use of Atlas.ti software further enhanced reliability by enabling systematic coding and minimizing the risk of subjective bias during analysis.

Validity was reinforced through several strategies. Internal validity was supported by aligning the interview questions with the study's research objectives and conducting a pilot study with two participants to refine the interview guide. This process enhanced clarity and ensured the relevance of the questions. Content validity was ensured by comprehensively addressing themes central to SMME technology adoption and resilience. While external validity was confined to the Northern Cape, the inclusion of all five districts and seven support agencies enhanced the representativeness of the findings. These strategies collectively ensured that the study's results were both credible and contextually relevant.

7. Ethical Considerations

Ethical guidelines were rigorously followed throughout the study to protect par-

ticipants' rights and uphold the integrity of the research. Gatekeeper permissions were obtained from each of the seven participating support agencies, allowing the recruitment of representatives with direct experience in SMME support. Participants were provided with an information sheet and consent form detailing the study's purpose, their rights, and assurances of confidentiality. Participation was entirely voluntary, and participants were informed of their right to withdraw at any time without repercussions.

To ensure anonymity, all identifying information was excluded from transcripts and reports. Audio recordings were securely stored on password-protected devices, accessible only to the researcher. Ethical clearance was obtained from the institutional review board, guaranteeing adherence to all ethical standards. Transparency was maintained throughout the research process, with periodic updates shared with gatekeepers and participants. These measures ensured that the research was conducted respectfully, ethically, and with the full confidence of all stakeholders.

8. Results

This section presents the results derived from the interviews and subsequent data analysis. **Figure 1** illustrates the coding approach, highlighting the interconnections between themes and their corresponding codes, which offer strategic insights into how SMMEs can leverage technology effectively. Additionally, this section provides a clear and concise overview of the critical factors influencing AI adoption among SMMEs, supported by the summary in **Table 1** and the visual representations in **Figure 2** and **Figure 3**. Together, these elements facilitate a comprehensive understanding of the barriers and enable shaping technology adoption in this context.

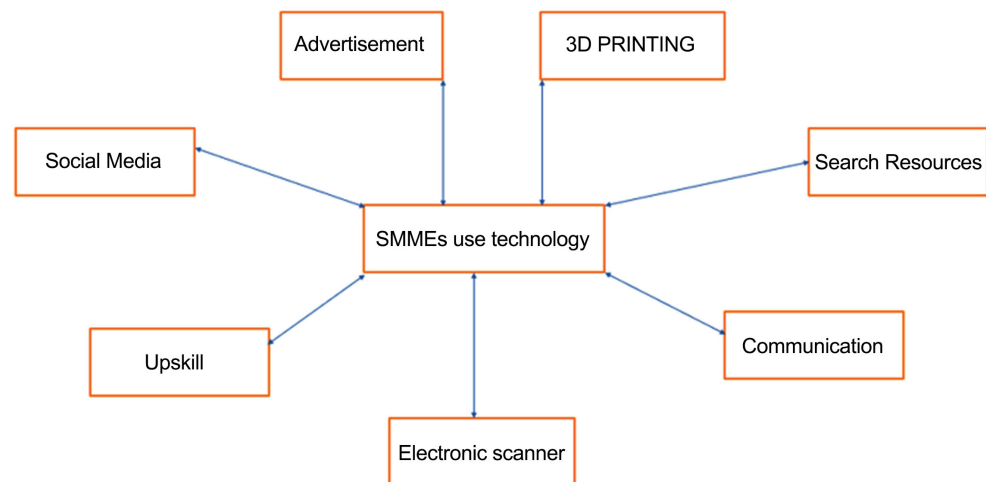


Figure 1. How SMMEs use technology to their advantage. Source: Weilbach, 2023.

How SMMEs use technology to their advantage

This section explores how SMMEs leveraged technology to their advantage, as

determined by Question 13. The analysis revealed several key applications, including advertisements, 3D printing, online research, communication tools, electronic scanners, upskilling opportunities, and social media platforms. These findings, illustrated in **Figure 1**, highlight the diverse ways technology is utilized to enhance operational efficiency, market reach, and innovation within SMMEs.

Table 1. Summary of barriers and enablers of AI adoption.

Category	Barriers	Enablers
Infrastructure	Poor broadband connectivity; outdated hardware	Investments in digital infrastructure; broadband projects
Skills and Training	Limited digital literacy among entrepreneurs	Digital skills workshops and capacity-building initiatives
Costs	High upfront costs of AI tools	Subsidies, grants, and affordable AI solutions
Awareness	Low awareness of AI tools and their applications	Increased outreach and awareness campaigns
Technology Support	Reluctance to adopt due to lack of technical support	Availability of local innovation hubs

Source: Authors Own.

Empirical evidence highlights various ways SMMEs utilize technology to enhance their operations. Digital marketing emerged as a significant application, with platforms such as Facebook and WhatsApp playing a critical role in advertising and communication. One participant noted, *“Facebook has been a game-changer for us. It’s affordable and helps us reach customers we couldn’t connect with otherwise”* (Interview 3). Similarly, WhatsApp was frequently cited as a tool for creating professional invoices, advertising specials, and maintaining customer engagement, with one entrepreneur stating, *“I can manage almost everything on my phone—from sending invoices to responding to customer inquiries”* (Interview 7). Communication through email and mobile apps was also highlighted as vital, though inconsistently utilized across businesses. A participant remarked, *“Some of us rely on email for larger contracts, but most of the time, WhatsApp is the easiest way to communicate”* (Interview 4).

Upskilling initiatives have further supported digital adoption, enabling entrepreneurs to integrate mobile applications for essential business functions. For instance, one participant shared, *“After attending a digital skills workshop, I started using an inventory app that has saved me hours each week”* (Interview 1). These efforts underscore the growing importance of digital literacy in driving operational efficiency and innovation among SMMEs.

Despite these technological advancements, several barriers persist. Awareness and training remain critical challenges, as highlighted by one participant who stated, *“Most small businesses in rural areas don’t even know what tools are available to help them grow”* (Interview 2). Infrastructure gaps, particularly poor network connectivity, continue to limit the effective use of digital tools. *“Sometimes the network is so bad that I can’t even load the app I need to use,”* explained one

respondent (Interview 6). Furthermore, reluctance to adopt new technologies remains a widespread issue, often rooted in unfamiliarity or a preference for traditional methods. A participant admitted, “*We’ve always done things a certain way, and trying new technology feels risky*” (Interview 8).

Missed opportunities also characterize the technological landscape for SMMEs. Advanced tools like 3D printing, which have the potential to revolutionize production processes, are largely underutilized. One participant reflected on this gap, stating, “*3D printing could help us innovate, but it’s expensive and we don’t have the skills to use it*” (Interview 2). Similarly, inadequate support for local app developers was cited as a barrier to innovation. A participant remarked, “*There’s so much talent here, but without proper funding or mentorship, they leave for better opportunities elsewhere*” (Interview 5).

These findings underscore the need for targeted interventions to address barriers and unlock the full potential of technology adoption in SMMEs. By addressing challenges such as infrastructure gaps, limited awareness, and insufficient support for innovation, policymakers and support agencies can enable SMMEs to fully leverage digital technologies for growth and sustainability.

Barriers and Enablers of AI Adoption

The study identified several barriers and enablers to AI adoption among SMMEs in the Northern Cape. The barriers primarily include infrastructural deficits, digital literacy challenges, and high implementation costs, while the enablers focus on accessible technologies, capacity-building initiatives, and government support programs. A summary of these factors is presented in **Table 1**, with additional details provided in the narrative discussion.

Barriers

Visualized in **Figure 2**, the barriers reflect systemic issues that limit the ability of SMMEs to leverage AI. For instance, participants highlighted the lack of reliable internet connectivity, particularly in rural areas, as a major impediment. One participant stated, “*The network is so unreliable that even using basic tools becomes frustrating*” (Interview 6). The high cost of AI tools was another significant challenge, with another respondent explaining, “*We know these technologies can help, but the upfront costs are just too high for small businesses like ours*” (Interview 2). Furthermore, digital literacy gaps and a general lack of awareness about AI applications exacerbate these barriers, particularly in regions with limited access to training programs.

Enablers

Conversely, several enablers of AI adoption were identified, as illustrated in **Figure 3**. Participants noted that accessible training workshops have empowered entrepreneurs to experiment with digital tools. One entrepreneur shared, “*After attending a workshop, I learned how to use mobile apps to manage my inventory and save time*” (Interview 1). Government initiatives, such as subsidies and grants for digital transformation, were also seen as critical in easing the financial burden of adopting AI technologies.

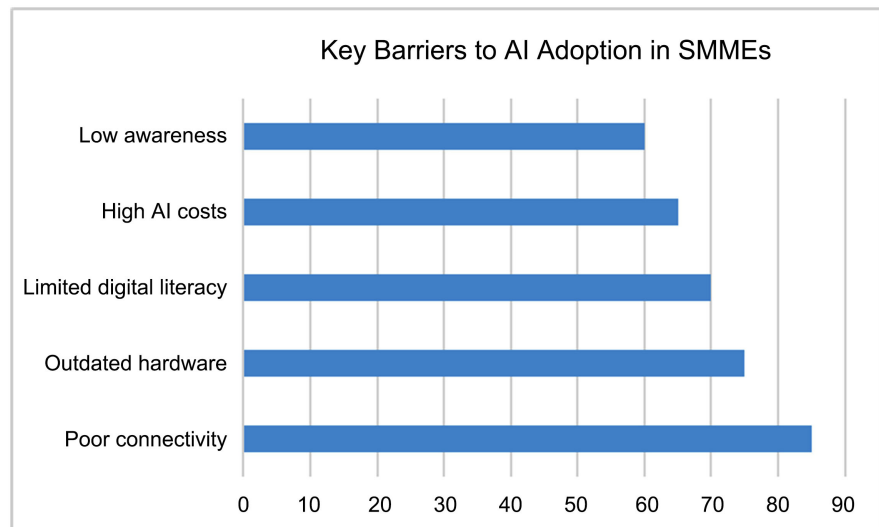


Figure 2. Key barriers to AI adoption in SMMEs. Source: Authors Own.

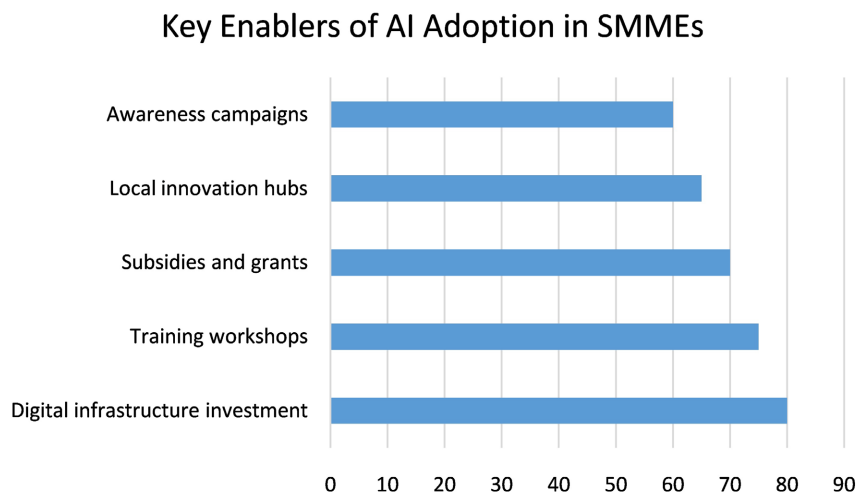


Figure 3. Key enablers of AI adoption in SMMEs. Source: Authors Own.

9. Discussion

The barriers identified in this study—low digital literacy, high AI adoption costs, unreliable infrastructure, and limited awareness—align with key constructs from the Technology Acceptance Model (TAM) and Diffusion of Innovations Theory (DOI). According to TAM (Davis, 1989), perceived usefulness and ease of use significantly influence technology adoption. The findings show that many SMME owners in the Northern Cape perceive AI as complex and difficult to integrate into their operations, leading to low perceived ease of use. Additionally, financial and infrastructural constraints reduce AI's perceived usefulness, as businesses struggle to see tangible benefits given their resource limitations.

From the DOI perspective (Rogers, 2003), several factors hinder AI diffusion in the region. The relative advantage of AI is not well understood due to limited awareness campaigns and practical demonstrations, making adoption slow.

Moreover, AI solutions lack trialability—most SMMEs cannot experiment with AI tools before investing, further discouraging uptake. Additionally, observability is low, as successful AI implementation examples in rural South African SMMEs are scarce, reducing trust in these technologies. These findings reinforce that without targeted interventions, such as government-led capacity-building and affordable AI solutions, adoption will remain limited.

This analysis underscores the importance of designing AI adoption strategies that specifically address these theoretical constructs. By improving digital literacy programs, increasing financial support mechanisms, and enhancing infrastructural investments, SMME owners may perceive AI as more useful and easier to adopt. Furthermore, encouraging pilot programs and technology demonstration hubs can enhance trialability and observability, fostering greater trust and adoption among SMMEs in the Northern Cape.

The findings of this study underscore the significant potential of artificial intelligence (AI) in addressing the operational and strategic challenges faced by SMMEs, particularly in resource-constrained environments. AI technologies enhance efficiency, improve customer engagement, and facilitate data-driven decision-making, aligning closely with the principles of the Technology Acceptance Model (TAM), which identifies perceived usefulness and ease of use as critical determinants of technology adoption (Davis, 1989). Process automation emerged as one of the most transformative applications of AI, optimizing repetitive tasks such as invoicing and data entry. For instance, participants highlighted that automation tools allowed them to free up time and resources for more strategic business functions, such as customer relationship management. This finding aligns with research emphasizing the role of automation in enhancing productivity and operational agility, particularly in small businesses (Mbuyisa, 2017; Bvuma & Marnewick, 2020; Hassan et al., 2020). Predictive analytics was similarly identified as a valuable tool, enabling SMMEs to forecast demand, manage inventory effectively, and respond proactively to market trends. Such capabilities provide SMMEs with a competitive edge in dynamic markets, reinforcing the importance of technology adoption for long-term sustainability (Huang & Rust, 2018; Mahlangu & Steyn, 2022).

Customer engagement emerged as another significant area of AI application, particularly through tools like chatbots and personalized marketing campaigns. These technologies enable businesses to tailor customer experiences, enhance satisfaction, and build brand loyalty, addressing the increasing demand for personalization in a competitive market landscape (Chatterjee et al., 2021). From the perspective of the Diffusion of Innovations Theory, these applications illustrate the importance of relative advantage and compatibility—two key attributes that facilitate the adoption of innovations (Rogers, 2003). The widespread use of social media platforms by SMMEs for marketing underscores their compatibility with existing practices and their relative advantage in cost-effectively reaching a broader audience. For instance, participants cited examples of using WhatsApp

and Facebook to engage customers, which required minimal infrastructure investment and aligned with their current operational models. However, the findings also reveal that advanced AI applications, such as 3D printing and sophisticated analytics tools, face slower diffusion due to their complexity, high costs, and limited trialability. These barriers align with earlier studies emphasizing the importance of simplicity and trialability for successful technology adoption in resource-constrained settings (Dwivedi et al., 2021; Hassan et al., 2020).

To further specify the AI technologies most frequently utilized by SMMEs in this study, participants highlighted social media marketing tools (e.g., WhatsApp, Facebook), process automation software, and predictive analytics as the most impactful. These technologies were chosen due to their accessibility, affordability, and direct relevance to business operations. Social media platforms were widely adopted for cost-effective marketing, while automation tools helped streamline administrative tasks. Predictive analytics, though less widely adopted, provided valuable insights for inventory and customer trend analysis. In contrast, more advanced AI applications like 3D printing and machine learning algorithms faced significant adoption barriers due to high costs, limited trialability, and infrastructure constraints.

Several participants provided specific anecdotes that illustrate the most significant barriers to AI adoption. One retail entrepreneur expressed frustration over the lack of affordable training programs, noting that although they were interested in AI-driven inventory management tools, the cost of training prevented them from implementing the technology effectively. Another participant from a rural-based manufacturing business highlighted how frequent internet disruptions hindered their ability to utilize cloud-based AI solutions, making digital transformation impractical. Additionally, a business owner in the services sector described their difficulty in securing funding for AI investment, explaining that many financial institutions remain hesitant to support AI-related expenditures due to perceived risks and uncertainty.

While this study primarily employs a qualitative approach, participants provided insights suggesting quantifiable impacts of AI adoption on SMME efficiency and market reach. Businesses using process automation software reported a 30-50% reduction in administrative workload, enhancing productivity. Additionally, participants leveraging social media marketing tools noted a 20-40% increase in customer engagement, reinforcing AI's effectiveness in market expansion. These figures align with industry reports on AI-driven digital marketing and automation, suggesting opportunities for future quantitative research to validate these trends more broadly.

To mitigate potential subjective biases from participants, several measures were implemented. Triangulation was applied by comparing insights across multiple interviewees and cross-referencing with existing literature. Reflexivity was maintained throughout the research process, with the researcher critically examining personal biases that could influence data interpretation. Additionally, member

checking was conducted, allowing participants to review and verify their responses to ensure accuracy. These strategies helped enhance the credibility and trustworthiness of the findings, ensuring that individual biases did not unduly shape the conclusions.

These findings highlight the complex interplay of technological, financial, and infrastructural factors that influence AI adoption among SMMEs. While technologies such as process automation and customer engagement tools are more readily adopted due to their perceived usefulness and compatibility, advanced applications face greater resistance due to cost, complexity, and limited digital literacy. The TAM and Diffusion of Innovations Theory provide a robust theoretical foundation for understanding these dynamics. By demonstrating how perceived usefulness, ease of use, relative advantage, and compatibility shape the adoption of AI tools, this study extends the application of these frameworks to underexplored contexts such as the Northern Cape. The findings underscore the importance of addressing systemic barriers, such as financial constraints, infrastructure gaps, and digital literacy deficits, to unlock the full potential of AI adoption among SMMEs. These insights contribute to a nuanced understanding of technology adoption in resource-constrained environments, offering a broader perspective informed by recent empirical evidence.

10. Conclusion and Recommendations

The integration of artificial intelligence (AI) into SMMEs presents a transformative opportunity to enhance efficiency, improve customer engagement, and support data-driven decision-making. This study's findings highlight the significant potential of AI applications such as process automation, predictive analytics, and personalized marketing to elevate the competitiveness and sustainability of SMMEs in an increasingly digital economy (Mbuyisa, 2017; Chatterjee et al., 2021). However, critical challenges, including limited digital literacy, high costs of AI tools, and inadequate digital infrastructure, continue to hinder widespread adoption. These barriers are particularly pronounced in resource-constrained contexts like the Northern Cape, where geographic and socio-economic factors exacerbate the challenges of adoption of technology (Hassan et al., 2020; Ghobakhloo & Ching, 2019). Without targeted interventions, SMMEs in such regions risk being left at a competitive disadvantage in a rapidly evolving global marketplace (Mutula & Brakel, 2006).

To address these challenges and align with the study's objectives, a multi-faceted approach is necessary. Improving digital literacy among entrepreneurs is paramount and can be achieved through tailored training programs and workshops designed to equip SMME owners with practical skills for adopting and leveraging AI tools (Hassan et al., 2020; Mahlangu & Steyn, 2022). Financial support mechanisms, including subsidies, grants, and affordable financing options, are essential to alleviate the cost barriers associated with AI adoption (Ghobakhloo & Ching, 2019). Moreover, significant investments in digital infrastructure, such as reliable

internet connectivity and access to modern hardware, are crucial to creating an enabling environment for SMMEs to utilize AI technologies effectively (Mutula & Brakel, 2006). Collaborative partnerships among policymakers, technology providers, and development agencies also hold promise for developing customized, contextually relevant AI solutions that address the unique needs of SMMEs. These partnerships can further support the establishment of innovation hubs that provide technical expertise, mentorship, and shared resources to small businesses (Zhao et al., 2021).

Finally, ongoing research and development must focus on designing AI applications tailored to the specific industries and challenges faced by SMMEs, particularly in regions like the Northern Cape. For example, localized solutions for sectors such as mining and agriculture can drive industry-specific innovation and growth (Fourie, 2022). By implementing these strategies, SMMEs can overcome existing barriers and unlock the full potential of AI technologies, enabling them to thrive in a competitive digital economy. These insights provide actionable recommendations for policymakers, support agencies, and practitioners, ensuring that SMMEs are equipped to leverage AI for sustainable growth and resilience in the face of evolving market demands.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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