Chapter 10. Human-Machine Collaboration in Sub-Saharan Africa: Bridging the Skills Gaps and Infrastructure Challenges

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Abstract

Africa's large population faces high unemployment, underscoring the critical importance of livelihood strategies. Artificial intelligence's (AI) potential to transform work offers opportunities but also threatens the under-skilled workforce. Therefore, this study investigated Sub-Saharan Africa's efforts to ensure human-machine collaboration to address the challenges of unemployment and related issues of poverty and high inequality. A systematic literature review was conducted to examine studies published between 2020 and 2025. Using the Sustainable Development Goals (SDGs) framework and the capability approach, it analysed how human-machine collaboration influences progress toward achieving the United Nations Agenda 2030. Findings reveal that the region is unable to benefit from advanced technologies. Additionally, challenges related to infrastructure, digital and AI literacy, telecommunications, and transportation affect business success. With a willing youth population, the region offers universities opportunities to introduce AI curricula and forge private-sector partnerships that equip students with practical AI skills. These findings contribute to the digitalisation literature and highlight potential avenues for skilling and reskilling the SSA's workforce to coexist with AI systems. Policymakers should prioritise digital transformation to prevent inadequate infrastructure from hindering the region's development. Addressing these challenges creates opportunities for the region and accelerates progress toward the SDGs.

Keywords: artificial intelligence, human-machine collaboration, skills, employment, digital transformation, Sub-Saharan Africa.

Introduction

Human-Machine collaboration is a vital component of Work 5.0, highlighting the development of human capabilities and decision-making beyond their replacement by automation (Mourtzis et al., 2023). Human-machine collaborations are social-technical systems whereby humans and technology work together to complete tasks. This type of partnership is characterised by automation and technical autonomy (Jarrahi et al., 2023). Automation refers to instances in which technological systems replace tasks formerly performed by humans, generally to increase productivity by reducing direct human engagement in activities (Simmler & Frischkencht, 2021). However, substituting for human input, human-machine collaboration improves performance by integrating human and machine strengths, whereby each contributes to tasks for which they are best suited (Kolbeinsson et al., 2019). Others argue that these technologies threaten job security, especially in labour- intensive sectors (Mvile & Bishoge, 2024). Therefore, human-machine collaboration requires evaluating the tasks performed by humans and machines, as well as the degree of autonomy afforded to technological systems (Simmler & Frischkencht, 2021; Kolbeinsson et al., 2019).

This chapter investigates how human-machine collaboration can address socio- economic issues and identify gaps to be addressed in preparing Sub-Saharan Africa's (SSA) workforce to be artificial intelligence (AI) literate, not to threaten job security. The noted technical needs include infrastructure challenges, an unstable electricity supply, and limited digital connectivity, which hinder effective technological implementation in SSA (Bakibinga-Gaswaga et al., 2020). Human-machine collaboration is essential because automation creates structural job changes rather than displacement, as machines require human support (Vermeulen et al., 2018).

The impact of human-machine interaction has been widely researched (Kolbeinsson et al., 2019; Morutzis et al., 2023; Simmler & Frischkencht, 2021; Wang & Li, 2025), but research in the African context remains limited. This study, therefore, fills this gap by synthesising findings from SSA on the topic. It provides recommendations for enhancing human-machine collaboration using the SSA case. Policymakers can thus align digital transformation efforts in ways that will not entrench existing educational and digital inequalities. Hence, elevating human-machine collaboration is crucial to foster inclusive growth and digital transformation (Das, 2024; Modiba et al., 2024) in SSA, harnessing its demographic potential and ensuring that technology is developed with and for the people. Therefore, the following research questions are posed to guide the review:

- What are the impediments to human-machine collaboration in SSA?
- How is human-machine collaboration embraced in SSA?
- How can human-machine collaboration address SSA's socio-economic issues?

Methods and Materials

Data collection for analysis entailed systematically retrieving peer-reviewed and grey literature. Materials were sourced from the ScienceDirect and Scopus databases and from Google for grey literature. Guided by the Preferred Items for Systematic and Meta-Analysis – PRISMA (Page et al., 2021), identified records were screened, appraised (Segooa et al., 2025), and seven were included in the study (see Figure 10.1).

Figure 10.1
Adapted PRISMA Flow Diagram
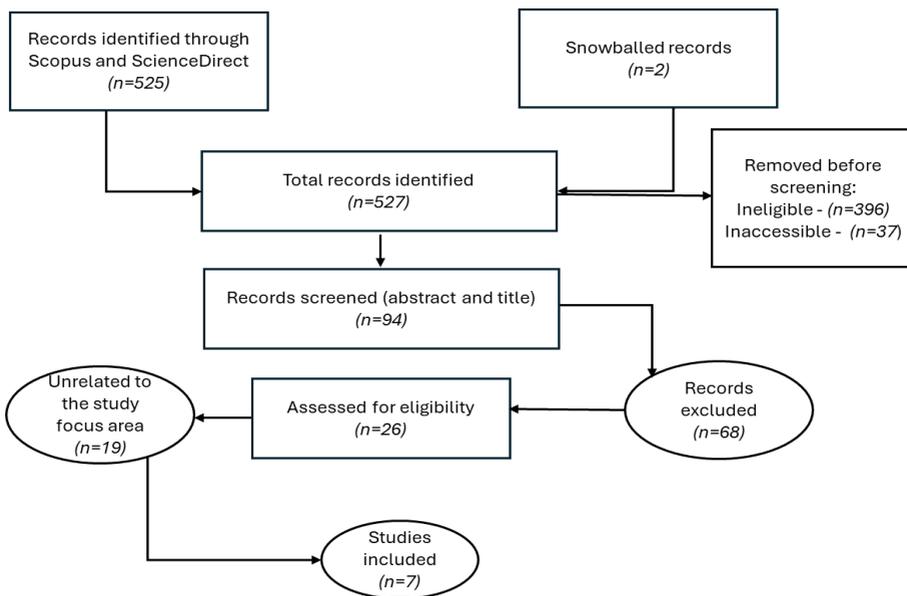
Note. Adapted from "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews" by Page et al., 2021, *BMJ, 372,* Article 71 (https://doi.org/10.1136/bmj.n71). Copyright 2021 BMJ Publishing Group Ltd.

Using the search string "human machine collaboration AND digital transformation AND Sub-Saharan Africa AND employment AND infrastructure," the databases were searched and filtered according to the inclusion and exclusion criteria in Table 10.1.

Table 10.1

Inclusion and Exclusion Criteria

Inclusion	Exclusion
- Sub-Saharan Africa	- Regions outside (SSA)
- Studies on human-machine collaboration, AI integration, skills gap, workforce displacement, and digital transformation	- Studies not addressing human-machine collaboration, AI, workforce issues, digital transformation
- English studies	- Non-English studies
- Research articles	- Conference proceedings, reviews, book chapters, encyclopaedias
- Period between 2020 and 2025	
- Full-text available through institutional access	- Before 2020 and after 2026
	- Inaccessible texts

Theoretical Framework

The capability approach suggests that people require specific skills to support their capacity to change their life situations (Sen, 2005). It also argued that this approach can be used to test how specific technologies impact people's lives (Modiba & Kaye, 2023). In the case of technologies such as AI, the capability approach can help identify skill deficiencies and how to address them to enable human-machine collaboration (Bobitan et al., 2024). The SDG framework presents 17 goals with corresponding targets (UN, 2025) that countries can use to track their progress in addressing challenges to sustainable development. For this study, SDGs 1 (no poverty), 2 (zero hunger), 4 (quality education), 8 (decent work and economic growth), 9 (industry, innovation, and infrastructure), and 10 (reduced inequalities) will be used to evaluate how the use of technology impacts sustainable development.

While other scholars use theories such as institutional enactment, systems theory, and the sustainable livelihood framework, sustainable development, diffusion of innovation, and resilient theory (Nahar, 2024; Wang & Li, 2025), these were not deemed suitable for this study, given that the human aspect is the key focus. Therefore, the SDG framework is used in conjunction with the capability approach to analyse the data using content and thematic analysis.

Socioeconomic Context of Human-Machine Collaboration

Human-machine collaboration uses technologies such as AI, Augmented Reality (AR), and Virtual Reality (VR) to enhance human skills and decision-making (Isaza & Cepa, 2024). These advanced technologies reconfigure tasks, automating, shifting, or eliminating roles, requiring workers to adapt (Agreli et al., 2021). Thus, AI can work alongside people rather than replace them (Hudson, 2025; Resh et al., 2025).

The Sub-Saharan African (SSA) labour market is characterised by informality, with 86% of jobs (excluding agriculture) under this sector (Hanine et al., 2024). Thus, technology adoption is constrained by cost considerations.

However, it is believed that labour-intensive industries such as manufacturing may adopt advanced technologies, thereby threatening technological and inclusive development (Arruda & Pimenta, 2024).

Sub-Saharan Africa's education systems face severe inequality and limited digital access; only 6% of schools have internet access, which is the lowest proportion globally (Langthaler & Bazafkan, 2020). This lack of internet access could exacerbate socio-technical disparities rooted in limited electricity access and expensive hardware and data costs, thereby impeding skill acquisition related to digital platforms and AI (Chakroun et al., 2019). Thus, improving educational equity is essential for technology adoption.

Sub-Saharan Africa's large youth population offers a demographic dividend if employment challenges are addressed (Mamphiswana & Bekele, 2020). The projected population growth of 2.5 billion by 2050 requires 1.1 billion new jobs (Hanine et al., 2024). However, there are concerns about whether youth are acquiring the skills required for the Fourth and Fifth Industrial Revolutions (Masilo, 2025). Realising this potential requires significant investment in human capital and in institutions capable of absorbing the workforce.

Skills Gaps and Intelligent Machines

An extensive skills gap separates the demands of the 4IR economy from the SSA workforce. To compete, they need to develop foundational and intermediate digital skills, including AI literacy (Banga & te Velde, 2019; Bobitan et al., 2024).

Technical skills, such as problem-solving and data analysis (Bashir & Daniels, 2022), and soft skills, such as judgment, communication, and adaptability (Chigbu & Makapela, 2025), are also critical. The skills challenge stems from the misalignment between educational and industry needs. Nevertheless, traditional education systems are often of low quality and fail to teach digital and problem-solving skills (Okoye et al., 2024). Therefore, there is a need to equip graduates with complementary digital, technical, and soft skills to alleviate the region's high unemployment.

Infrastructure Constraints and Digital Readiness

Energy access affects digital readiness. Only 70% of communities in SSA have access to electricity, which also affects broadband access, the rollout of digital technologies, and ICT use (Tryphone et al., 2023). Connectivity is uneven: while mobile broadband covers 81% of the population, only 30% are online, particularly in rural areas, underscoring the need for targeted infrastructure policies (Alper & Miktus, 2019).

Sub-Saharan Africa lags other regions in digital technology adoption, resulting in a digital divide (Astuti & Ayinde, 2025; Wang & Li, 2025). Human capital, infrastructure, and political stability all influence these disparities.

According to Das (2024), when organisations show a seamless integration of ICT, IoT, and AI, it can be assumed that digital transformation has been achieved. Therefore, where disparities exist, equitable access requires reconsideration.

Sectoral Experiences of Human-Machine Collaboration

According to Chigbu and Makapela (2025), human-machine collaboration underlies Industry 5.0 (I5.0), Education 5.0, and Work 5.0, emphasising capability augmentation rather than replacement. This collaboration leverages human strengths, such as decision-making and creativity, while AI automates routine tasks. However, risks such as deskilling and surveillance can threaten autonomy, requiring trust and transparency in design.

Automation is likely to emerge first in capital-rich sectors such as mining and high-wage manufacturing, where global firms already use robotic loaders and trucks (Gaus & Hoxtell, 2019). As noted by Anosike et al. (2024), Intelligent Agriculture (IA) is used for food security, leveraging technologies such as IoT. However, they face financial, technological, and political barriers. Moreover, small businesses in the region's manufacturing sector are adopting Industry 4.0 technologies, but still lag international competitors (Peter et al., 2023). Therefore, financial support is crucial for the adoption of AI and IA.

The adoption of AI in SSA public administration faces challenges related to accountability, inclusion, and integrity. However, e-governance is improving transparency, but there are concerns about marginalising public personnel (Plantinga, 2024). Artificial intelligence is transforming healthcare in SSA, increasing diagnostic accuracy (e.g., 92% for tuberculosis) and enabling predictive analysis to reduce outbreaks by up to 85% (Serge Andigema et al., 2025). AI-powered telemedicine also improves resource allocation and access to healthcare in low-resource areas.

Results and Discussions

The findings are presented in accordance with the research questions set out in the chapter. The use of advanced technologies remains generally low in the reviewed records, with the discussion centering on how AI technologies might be used to support various business processes, summarised in Table 10.2.

Impediments to Human-Machine Collaboration in SSA

Results from Kenyan small businesses indicate an interest in using AI tools, though they have not yet been adopted (SSA-2). The study highlighted limitations of current human-AI interactions, which are predominantly two-way and misaligned with the relational, decentralised structure of Kenyan businesses. This underscores the need for context-responsive, customised technologies. The latter is emphasised by prompt engineering, which may fail to collaborate with users if prompts are not carefully developed, thereby confirming the AI skills cited by Banga and te Velde (2019). It also signals a need for locally designed AI technologies. SSA-1, SSA-3 and SSA-4 cite a lack of skills as an impediment to adopting AI tools, thus affecting human-machine collaboration.

Table 10.2

Summary of Findings

Identifier	Source	Country	Key Findings
SSA-1	Dlamini & Ndzinisa (2025)	SSA	AI could increase existing social disparities. AI-supported education is required for digital literacy
SSA-2	Ankrah et al. (2025)	Kenya	The individualised interaction between humans and AI in the business sector is community-driven. Prompt engineering is limiting collaboration
SSA-3	Takawira & Pooe (2025)	South Africa	SME equipped for I5.0. Financial investment, skilled workers, and digital infrastructure are key enablers
SSA-4	Okoruwa et al. (2022)	SSA	Low-skilled workers are affecting technology adoption. Lack of infrastructure and the digital divide hinder the adoption of emerging technologies
SSA-5	Klenam et al. (2025)	SSA	AI is reducing the cost of additive manufacturing. Machine learning handling large datasets
SSA-6	David-Olawade et al. (2025)	Nigeria	Lack of AI foundational knowledge
SSA-7	Armar et al. (2025)	SSA	The adoption of advanced technologies in SSA faces significant hurdles. Improving delivery systems can address infrastructural limitations

SSA-6 highlights limited AI knowledge and awareness of AI applications as another challenge affecting this human-machine engagement. Infrastructural challenges constitute a significant hurdle to accessing these technologies (SSA-1; SSA-4; SSA-5; SSA-7). SSSA-1and SSA-7 also mention low internet usage in the region, aligning with Alper and Miktus (2019) and Tryphone et al. (2023). Financial resources and affordability were cited as another hindrance (SSA-3; SSA-4; SSA-7; Anosike et al., 2023). SSA-4 and SSA-6 argue that policy formulation processes and governance issues also affect the adoption of advanced technologies.

Embracing Human-Machine Collaboration

The Kenyan study highlights small businesses' interest in adopting AI technologies. SSA-1 report on AI-powered tools used in the region, such as chatbots to triage resources (Rwanda), drought forecasting drones (SA), blood delivery systems (Ghana), and satellite imagery and vulnerable group identification (Togo). They, however, emphasise the need for tools to be contextually relevant and designed to meet local needs, particularly the social capital valued by these

businesses. As noted by SSA-1, the proliferation of AI technologies in the region can potentially exacerbate existing disparities. Like the digital divide that continues to hinder digital transformation in the least connected areas (Modiba et al., 2024), there is a need to manage the adoption of digital technologies. The proposed conceptualisation by SSA-2 presents a radical technology adoption. The collaboration between people and AI should therefore shift from individual-AI interaction to community-AI, thereby strengthening collaboration between humans and machines. In additive manufacturing (AM), AI is used to manage production and design processes and to handle large datasets (SSA-5). However, the collaborative aspect is still lacking. Healthcare students in Nigeria expressed interest in AI training and believed that its integration into healthcare would improve patient outcomes (SSA-6). The need for training supports Peter's (2023) findings.

Human-Machine Collaboration Potentially Addressing Socio-Economic Issues in SSA

It can be used to identify vulnerable people in need of aid, support the provision of quality education and health services, and help tackle the SDGs by generating inclusive solutions to address existing inequalities, provided AI models are well-trained (SSA-1). It can further assist with optimising work, addressing upskilling and data management challenges in resource-constrained business sectors (SSA-2; SSA-7). Work optimisation could be viewed as a threat to those who need to be absorbed in the labour market. Job creation and the formalisation of sectors are other benefits of these advanced technologies (SSA-4; SSA-5). SSA-3 argues that with I5.0 collaborative robots (cobots) present the ultimate human-machine collaboration that will improve operation of small businesses through enhanced employability with cobots working alongside human, improved productivity (SSA-7), and job satisfaction through the combination of human creativity and problem solving and machine precision, supporting literature findings of Chigbu and Makapela (2025); Hudson (2025) and Resh et al. (2025). Within the AM space, it can foster regional inclusive industrialisation and reduce dependence on imports for critical systems (SS-5). The above findings indicate that skills and infrastructure are major factors affecting human-machine collaboration. While the CA argues that with skills, people are able to create and adopt opportunities before them, the infrastructural issue is a significant impediment because it takes away possibilities for those without adequate infrastructures, limiting their abilities to acquire and sharpen their digital and AI skills to be prepared for the 5.0 to collaborate and co-create with AI tools. This means that this limitation affects some communities in SSA in addressing issues of poverty and zero through participation in the digital economy and access to quality education that equips them with such skills (SSA-1). Figure 10.2 illustrates the noted gaps that the digital transformation agenda could address and the SDGs that could be achieved through the proposed collaborations.

Figure 10.2

Human-Machine Collaboration for SDG Attainment
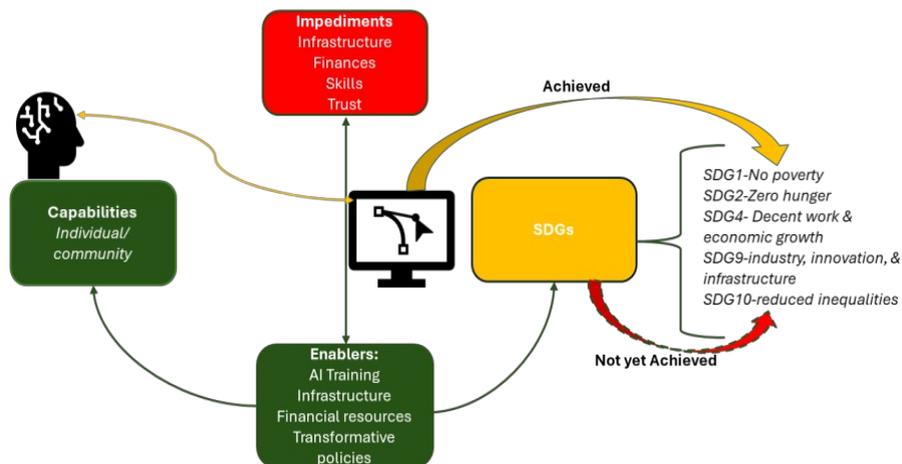
The framework shows that when capabilities are nurtured, humans can learn the requisite AI skills to work together with the tools to help solve socio-economic problems that humans understand well. Forging their creativity and machine competencies, the region can also develop technologies that resonate with communities' needs.

Conclusion

Human-machine collaboration is a key feature of Work 5.0 and is crucial for SSA, as it promotes augmentation and complementarity, enabling job creation rather than job displacement. Nevertheless, successful implementation faces substantial barriers: a significant skills gap and inadequate infrastructure, such as unreliable electricity and limited connectivity. These challenges may exacerbate the digital divide and hinder the region's capacity to develop contextually and culturally relevant AI tools.

Achieving inclusive development requires a multifaceted approach, including reforms to the education system, the development of digital and socio-behavioural skills, and investments in smart, integrated infrastructure, typically fostered through public-private partnerships. The future of work in SSA depends on ensuring that technology is developed for and with the people of the region.

This study's scope was limited to two academic databases. Future research should pursue comparative studies across SSA countries and use empirical methods to investigate the practical implementation of human-machine systems in various work contexts.

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