# Harnessing fourth industrial revolution (4IR) technologies for sustainable development in Africa: a meta-analysis

Lucy Kibe, Tom Kwanya and Hesbon Nyagowa
*Technical University of Kenya, Nairobi, Kenya*

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## Abstract

**Purpose** – The fourth industrial revolution (4IR) has changed the way people operate. All sectors of the economy have been affected by this technological advancement. However, little is known of how 4IR technologies are used in Africa. This paper aimed to investigate how 4IR technologies can be harnessed to support sustainable development in Africa. The objectives of the study were to: examine the infometric patterns of research production on 4IR technologies for sustainable development in Africa; explore the perception of 4IR technologies and their potential for sustainable development in Africa; investigate the extent to which 4IR technologies have been harnessed to support sustainable development in Africa; determine the factors influencing the use of 4IR technologies for sustainable development in Africa; and identify the strategies which can be used to harness 4IR technologies for sustainable development in Africa.

**Design/methodology/approach** – The study applied a mixed methods research approach. Quantitative data was collected through bibliometrics analysis while qualitative data was collected by use of systematic literature review. Data was collected from Google Scholar using Harzing's "Publish or Perish" software and analysed using Microsoft Excel, Notepad, VOSviewer and Atlas.ti and presented using tables, graphs and figures.

**Findings** – The study retrieved 914 research publications on 4IR and sustainable development in Africa. It emerged that production of research on the subject has increased gradually over the years. The findings reveal that Africa is aware of the potential of 4IR for sustainable development. In fact, it emerged that 4IR technologies are being used to support education, health services, tourism, e-commerce, records integrity and project management. Some of the factors that inhibit the use of 4IR for sustainable development Africa include lack of relevant policies, low skill levels in 4IR technologies, inadequate infrastructure and lack of stakeholder involvement. This study recommends the development of policies in 4IR, capacity building and upgrading of infrastructures. The findings can be used by governments in Africa to harness 4IR technologies for sustainable development.

**Originality/value** – The research is original in scope and coverage.

**Keywords** The fourth industrial revolution, Sustainable development, Artificial intelligence, Blockchain, Africa

**Paper type** Research paper

## 1. Introduction

Technology progress in different fields, for example, artificial intelligence (AI), big data analytics, cloud computing, cyber security and the Internet of things (IoT), amongst others, have brought about the fourth industrial revolution (4IR) (Asghar *et al.*, 2020). The 4IR can be traced back to the advancements of the first to third revolutions. The invention of the steam engine triggered the first industrial revolution in the 18th century. It used water and steam to automate the manufacturing of products (Schwab (2016). The second industrial revolution (2IR) was witnessed in the 19th century and was characterised by widespread electrification or the use of power for mass production. The third industrial revolution (3IR) can be traced to the 1960s when there was advanced computing. The world began to use information technologies to automate production and workflows. In 2016, Schwab Klaus, the chair of the World Economic Forum, coined the term 4IR. He indicated that 4IR was mainly building on the 3IR. An amalgamation of physical, digital and biological technologies characterises it. It encompasses

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robotics, machine learning and data science (Asghar *et al.*, 2020). According to Schwab (2016), 4IR is not only about the continuation of 3IR but rather an arrival of a new era distinct from the other. It is different in three ways; velocity, scope and impact of the systems in the 4IR.

The arrival of the 4IR brought about the potential to attain sustainable development by integrating technology into economic production (Peters and Rakshit, 2019). For example, the Association of South Asian Nations (ASEAN) indicated that the 4IR could be used to grow their three pillars, including political security and sociocultural and economic communities (Menon and Fink, 2019). The 4IR autonomy nature gives it the potential in data management and monitoring and public service efficiency, policy management, governance and production towards economic and social change (Nalubega and Uwizeyimana, 2019). Pantuliano (2020) asserts that 4IR technologies can drive development in areas such as detecting illegal mining and deforestation and managing environmental resources. The technologies can also help increase food production, introduce e-Learning, make education cheaper and widely accessible, and use smart solar systems to tackle electricity issues in rural areas. 4IR also has the potential to open up collaborations in regions and economic development through the digitalisation of government services (Lee *et al.*, 2020). According to Xu *et al.* (2018), the 4IR creates an information age that replaces traditional jobs with knowledge workers. These workers produce goods and services using their minds rather than their muscles. They provide organisations with creativity and leverage on the organisational data to generate insights for the future. 4IR is anticipated to help integrate different techniques and domains, improving the quality of lives and increasing connectedness.

## 2. Literature review

4IR technologies are increasingly being integrated into the day-to-day activities of organisations and industries (Mpofu and Nicolaides, 2019). This revolution can potentially increase economic growth in countries that adopt and exploit technologies. Countries like the United Kingdom (UK) and the United States of America (USA) have developed policies that guide the adoption and implementation of 4IR technologies in their jurisdictions (Zervoudi, 2020). It is, therefore, essential for developing countries to also take the leap of faith and adopt the 4IR technologies in order to gain from them. African countries risk stagnating in the digital divide and lowering their global competitiveness if they fail to adopt 4IR technologies (Chan, 2018). There are examples, however, of instances where 4IR has been used to harness sustainable development in Africa. These include:

### *2.1 Poverty reduction and inequality*

The use of 4IR technologies can assist in fighting poverty and inequality (Ndung'u and Signe, 2020). The use of digital technologies has increased access to information and job opportunities. 4IR has also facilitated the emergence of gig work and workers (De-Ruyter *et al.*, 2018). Technologies have created platforms where people with different skills can work and earn a living. Ultimately, this reduces the level of poverty in the countries. For example, AI, IoT, and blockchain technologies improve data gathering and analyses for targeted poverty reduction strategies. In Kenya, Mpesa mobile money transfer system has been used to empower ordinary citizens to conduct business and make seamless transactions that support their efforts toward poverty reduction (Natile, 2020).

### *2.2 Reinventing skills and workforce*

According to Nsengimana (2018), by 2030, the African workforce will be among the largest in the world. This growth will be pegged to the African countries tapping into the 4IR technologies by providing the essential infrastructure and skills needed in the tech world.

The 4IR will change the nature and needs of the job market, with workers being required to possess skills and capabilities to perform diverse tasks in digital workplaces.

*2.3 Financial services and investment*

4IR technologies have also increased financial services and investment. For example, Kenyan financial institutions use blockchain technology to verify customer records. Consequently, they have extended access to loans to many traders, especially in the informal sectors (Ndung'u, 2018). Blockchain facilitates the reduction of fraud through the verification and authentication of records.

*2.4 Improved agricultural sector*

In the agricultural sector, Africa is yet to tap the full potential of 4IR technologies (Ndung'u and Signe, 2020). Agriculture is the most significant economic sector in most African countries. Meaningful economic growth in these countries can only be listed with investment in this sector (Ehui, 2018). Some countries have tried to incorporate 4IR technologies in farming. Several African countries have made initial steps to integrate emerging technology into agriculture. Ghana uses mobile technology to disseminate weather information to farmers. Uganda uses the "Sparky Dryer" to dry out produce and reduce food waste (Kariuki, 2018). Nigeria uses technology to advise the farmers on which fertiliser to use by measuring the soil composition (Ehui, 2018).

*2.5 Improved health service*

Currently, mobile technology is used by many people as a source of medical data and services. In Uganda, health workers use mTrac mobile technology to report medicine stocks (Mutungi *et al.*, 2019). Also, Rwanda is the first to use drones to deliver health services. For instance, they transport blood for transfusion in remote places using drones (Nisingizwe *et al.*, 2022). In West Africa, during the Ebola breakout, the government used WhatsApp to communicate symptoms and all information relating to Ebola to the people and health workers alike (Atieno, 2017). Ethiopia also uses AI to diagnose cancer (Champlin *et al.*, 2017). IBM (International Business Machines Corporation) Research Africa uses AI via game theory and machine learning to help eradicate malaria in Africa (Akinwande, 2018).

Several factors inhibit the use of 4IR technologies for development, particularly in Africa. Some of the challenges include the following.

*2.6 Infrastructure*

Most African countries need more infrastructure to support the adoption of 4IR technologies (Asghar *et al.*, 2020). For instance, many African countries still need help with electricity issues. Also, when it comes to Internet penetration, African countries are still lagging compared with the developed world. Innovative industries which require effective Internet connection cannot operate in locations that lack this technology (Zhou *et al.*, 2015). Other challenges include a need for standardised programming interfaces, limited fibre optic connectivity as well as a need for interoperability of platforms.

*2.7 Regulatory framework to deal with 4IR*

4IR technologies bring about cybersecurity challenges as well. African countries are yet to develop comprehensive legal frameworks for techno-rich operations. For instance, there are no comprehensive legal frameworks for aspects of cybercrime and 4IR (Markowitz, 2019). Some countries like South Africa and Morocco have tried to support the development of companies that deal with information security (Van-Vuuren *et al.*, 2020). There is a need,

however, to develop adequate regulatory frameworks that govern the use of 4IR technologies and minimise their misuse. Pan-African bodies such as the African Continental Free Trade Agreement can act as the governance entities to coordinate the development of policies and procedures for 4IR technologies.

## 3. Context and rationale of the study

Udemezue and Hammond (2022) assert that Africa has grown tremendously in technology. The digital literacy level has also increased as of 2021, with many success stories of the use of technology being reported in different development fields. This creates hope for more achievements in the years to come, which will be based on technology. For example, Nigeria, Kenya, Egypt and South Africa received an 81% technology investment in 2021. The technologies that made the high investments were based on e-commerce, health and poverty reduction. The African technology scene is also thriving with the development of over four hundred technology hubs in the areas of 4IR. The hubs cover mobile technology, software engineering and blockchain technology (Giuliani, 2019).

Africa, which has many developing countries, has had an erratic development trajectory since the introduction of sustainable development goals (SDG). While most of the developed world has achieved a remarkable progression of their SDGs through technological advancements, Africa still lags (Goralski and Tan, 2020). Some of the challenges that African countries are facing in this regard are inequalities, the digital divide, poverty, health issues, poor infrastructure and low capital. Asghar *et al.* (2020) assert that by using emerging 4IR technologies, developing countries can achieve the SDGs. There is a need to urgently explore the potential of 4IR technologies in driving the attainability of the SDGs. This means that African countries need to start scaling up the adoption of these digital technologies to deliver the 2030 development agenda in time and ensure that the benefits of 4IR are realised optimally (Pantuliano, 2020).

The 4IR technologies hold great potential in accelerating the achievement of SDGs in Africa. One of the challenges holding back the potential of 4IR technologies in Africa is the need for Information and communication technologies (ICT) stills in the continent. Similarly, the continent needs enabling factors such as infrastructure, leadership and policies to fully support the adoption and implementation of 4IR technologies in different sectors of the economy. Therefore, developing countries have a long way to go before fully harnessing the potential of 4IR technologies in sustainable development. This study investigates how 4IR technologies can be harnessed for sustainable development in Africa.

### *3.1 Research objectives*

*RO1.* To examine the informetric patterns of research production on 4IR technologies for sustainable development in Africa;

*RO2.* To explore the perception of 4IR technologies and their potential for sustainable development in Africa;

*RO3.* To investigate the extent to which 4IR technologies have been harnessed to support sustainable development in Africa;

*RO4.* To determine the factors influencing the use of 4IR technologies for sustainable development in Africa; and

*RO5.* To identify the strategies which can be used to harness 4IR technologies for sustainable development in Africa.

## 4. Methodology of the study

This study applied a mixed methods research approach. Kwanya (2022) views mixed methods research as the roadmap for collecting, analysing and interpreting quantitative and qualitative data. The research used bibliometrics methods for quantitative data, while for qualitative data, it used a systematic literature review (SLR). According to Norton (2001), bibliometrics measures text and information associated with publications from a specific field. It helps to measure the number of publications, citations, and visibility of the research work (Kwanya, 2020).

On the other hand, an SLR is an approach to identifying, evaluating and synthesising written scholarly work (Kwanya *et al.*, 2021). Okoli and Schabram (2010) assert that SLRs are usually conducted with an open mind. This research will adopt a meta-analysis type of literature review. The study began with the quantitative component to acquire the literature for review.

The publications on 4IR for sustainable development in Africa were analysed. The documents analysed were books, journal articles, theses and conference papers. The documents were identified from Google scholar using Harzing's "Publish or Perish" software. Google Scholar was chosen because of its inclusivity and accessibility in Africa. It also provides a quick way to acquire documents published in different fields. Kwanya *et al.* (2021) argue that Google Scholar has no access restrictions and is essentially free. Therefore, it was a suitable platform to identify and retrieve literature for this study. The keywords and phrases used were "sustainable development", "4IR", "Fourth Industrial Revolution" and "Africa". The data was retrieved on August 26, 2022. The data was analysed using descriptive statistics and content analysis. This was done with Microsoft Excel, Notepad, Atlas.ti version 9 and VOSviewer version 8.

## 5. Findings of the study

The research yielded a total of 2,698 publications from the Google Scholar search. The data was cleaned based on the research scope and relevance. A total of 914 publications were identified as relevant to the study. The excluded publications were neither about nor published in Africa. There were no limitations on the year of publication of the materials. The 914 publications selected had all the keywords either in the title or in the content.

### *5.1 Infometric analysis of 4IR for sustainable development research in Africa*

*5.1.1 Quantity of research on 4IR technologies for sustainable development in Africa.* The cleaned data had 914 publications on 4IR for sustainable development in Africa. The oldest article was published in 2012, while the latest was published in 2022. Figure 1 shows the publication trends.


**Source(s):** Authors work

**Figure 1.**
Trends of publications on 4IR for sustainable development in Africa

Figure 1 indicates that the number of publications on 4IR on sustainable development in Africa has been on a steady increase from 2014 up to 2021. The drop observed in 2022 could be attributed to the fact that the year is still on-going, and more publications may be in press waiting to be published. As shown in Table 1, most of this research was published in journals (514), followed by conferences proceeding (337), handbooks (5), policy brief (1) and Research Gate (56) had project works in progress.

*5.1.2 Themes in 4IR on sustainable development research in Africa.* From the analysis of keywords in the titles of the publications, "fourth industrial revolution" was the most common phrase, with 154 appearances. This was followed by South Africa (82), Africa (78), industry (41), COVID (40), development (35), technology (30), AI (28), education (25) and sustainable development (17). Figure 2 shows the results. These themes indicate that most of the research has been conducted on subjects around 4IR, especially in South Africa. They are also around themes in education, development and industry development. South Africa is prominent because it has adopted 4IR technologies the most. The areas which have benefited

| Types of publication | Frequency |
|---|---|
| Journal articles | 514 |
| Conference proceeding | 337 |
| Handbooks | 5 |
| Policy briefs | 2 |
| Research gate (Project works) | 56 |

**Table 1.**
Types of publications

**Source(s):** Authors work

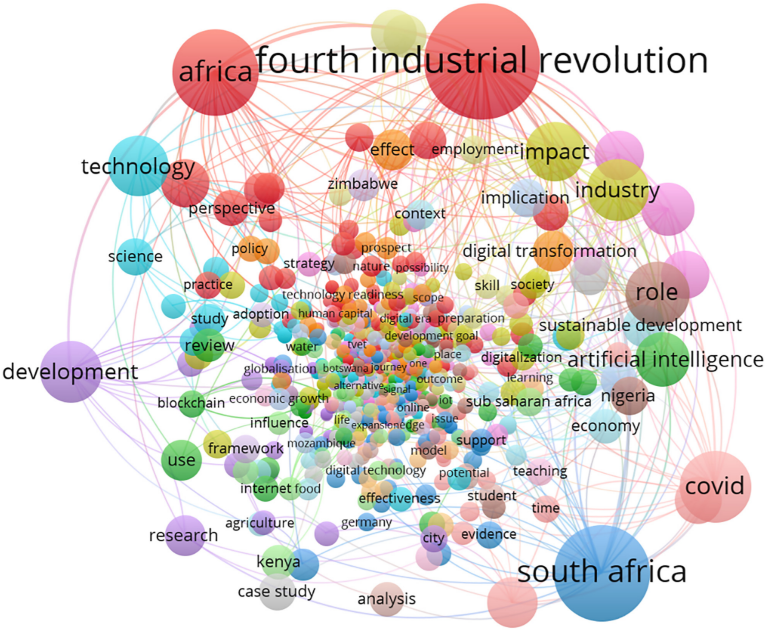



**Figure 2.**
Themes in 4IR for sustainable development research in Africa

**Source(s):** Authors work

from 4IR technologies include medical diagnosis, IoT for customer services and financial management via mobile technology (Agbehadji *et al.*, 2021).

*5.1.3 Quality of publications on 4IR for sustainable development in Africa.* In this paper, the authors believe that the quality of the research works can be assessed using the extent to which other researchers have used them through citation analysis (Kwanya *et al.*, 2021). The use of citations as a proxy of research excellence is well documented in the scientific literature (Haghighat and Hayatdavoudi, 2021; McManus *et al.*, 2022; Noorhidawati *et al.*, 2017). Some scholars, however, do not support this view and express their reservations about the objectivity of citations (Bonzi and Snyder, 1991). Nonetheless, it is the opinion of these authors that a research product that is cited the most is understood to be of a higher quality and impactful. More than half of the 914 publications still needed to receive a citation. The article with the highest number of citations had 339 citations. Overall, only two papers attained more than 100 citations. Table 2 shows the top ten cited papers.

### *5.2 Authorship of the research on 4IR in Africa*

Of the 914 publications, 371(41%) had been authored by a single author. This was followed by two authors, 256 (28%); three authors, 144(16%); four authors, 86(9%); five authors, 40(4%); six authors, 15(2%) and seven and eight authors each had one article. It is expected that the more authors, the more contributions they can make, but this is different from the data. It is also evident that the authors need to collaborate more in this field. Figure 3 shows the social network analysis of the authors. There are co-authorships between some authors, with C Aigbavboa (22) having many collaborations. This is followed by AN Matheri (12) A Ebekozien (11), E Lorenz (10), BS Paul (10), J Aliu (10), JC Ngila (10), W Viviers (10) and B Nyagadza (9).

### *5.3 Perception and potential of 4IR technologies for sustainable development*

From the literature reviewed, it emerged that citizens of African countries are aware of the 4IR technologies and their potential for sustainable development. Some of the excerpts from the literature are highlighted below:

| Cites | Authors | Title | Year |
|---|---|---|---|
| 339 | NW Gleason | Higher education in the era of the fourth industrial revolution | 2018 |
| 103 | W Naudé | Entrepreneurship, education and the fourth industrial revolution in Africa | 2017 |
| 86 | C Joynes, S Rossignoli, EF Amonoo-Kuofi | 21st Century Skills: evidence of issues in definition, demand and delivery for development contexts | 2019 |
| 74 | DT Ayentimi, J Burgess | Is the fourth industrial revolution relevant to sub-Saharan Africa? | 2019 |
| 69 | E Sutherland | The fourth industrial revolution–the case of South Africa | 2020 |
| 68 | A Doucet, J Evers, E Guerra, N Lopez, M Soskil | Teaching in the fourth industrial revolution: Standing at the precipice | 2018 |
| 64 | K Shulla, BF Voigt, S Cibian, G Scandone | Effects of COVID-19 on the sustainable development goals (SDGs) | 2021 |
| 59 | T Obradović, B Vlačić, M Dabić | Open innovation in the manufacturing industry: A review and research agenda | 2021 |
| 55 | A Ebekozien, C Aigbavboa | COVID-19 recovery for the Nigerian construction sites: The role of the fourth industrial revolution technologies | 2021 |
| 54 | C Kayembe, D Nel | Challenges and opportunities for education in the Fourth Industrial Revolution | 2019 |

**Source(s):** Authors work

**Table 2.** Top ten most cited publications on 4IR in Africa

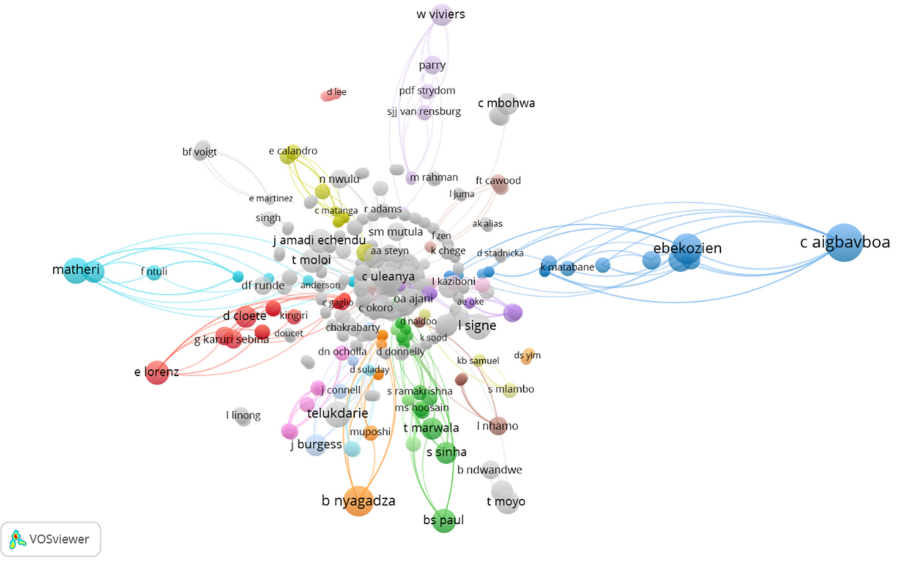



**Figure 3.**
Co-authorship on 4IR research in Africa

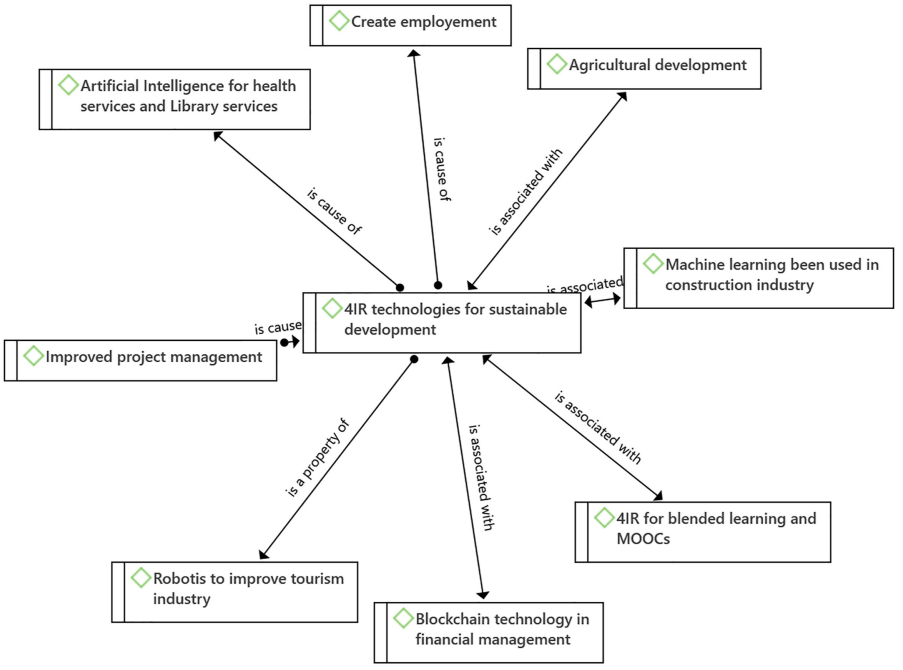
**Source(s):** Authors work

> . . . The 4IR can be used to upgrade poor people's lives in Sub-Saharan Africa . . . (Mhlanga, 2021a, b)
>
> . . . Considering current market demand amidst the fourth industrial revolution (4IR), we in the e-Business perceive that 4IR will be our platform to serve society in this era . . . (Alam *et al.*, 2022)
>
> . . . Fourth industrial revolution technologies are spreading fast, and in the next 10 years, they will influence Sustainable Development Goals (SDGs) . . . (Coulibaly, 2020)
>
> . . . AI could potentially benefit Africa in agriculture, building and construction, and policy initiatives in Africa . . . (Gwagwa *et al.*, 2021)
>
> . . . Fourth industrial revolution has potential implications for employment in the ICT sector, which is a crucial enabler of sustainable development in Africa . . . (Chandra and Pouchous, 2017)
>
> . . . Considering a substantial potential scope for blockchain, a digital revolution, referred to as the fourth industrial revolution . . . (Kuleto *et al.*, 2022)
>
> . . . Potential role of 4IR in the governance of medical records in Africa, which undermines human well-being and sustainable development in turn . . . (Niyitunga, 2022)

### *5.4 The extent to which 4IR technologies have been used for sustainable development*

From the literature, it emerged that some 4IR technologies have already been used to support sustainable development initiatives in Africa. This, however, was limited to just a few countries. Similarly, most of them were in their infancy stages. Figure 4 highlights how 4IR technologies have supported sustainable development in Africa.

Figure 4 reveals that 4IR technologies have supported diverse development initiatives in Africa. The sectors include health, information management, education, construction and job creation. The literature also indicated that 4IR technologies had been used to improve governance in human resource management and leadership.




**Source(s):** Authors work

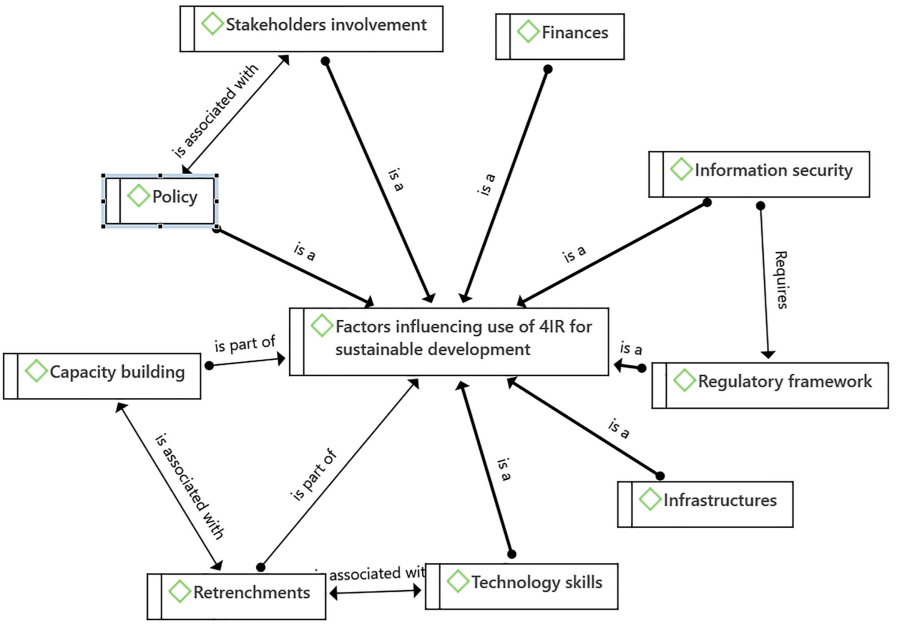
**Figure 4.**
Use of 4IR technologies to support sustainable development

*5.5 Factors influencing the use of 4IR for sustainable development*

From the content analysis, the documents reviewed highlighted different factors that have inhibited the full adoption of 4IR technologies for sustainable development. African countries need more regulatory frameworks to guide the adoption and use of 4IR technologies. For example, one publication called upon the Southern African Development Community (SADC) to develop a policy to guide the free trade area when trading under the 4IR (Markowitz, 2019). There also needed to be more stakeholder involvement in building knowledge on what 4IR is capable of in spurring sustainable development. The ICT ministries in most countries still needed to tap the benefits of 4IR technologies. Capacity building, technology skills and job security were highlighted factors that affected the adoption of 4IR technologies. 4IR technologies created a fear of job losses for many people needing advanced skills to work with the technologies. There were also concerns about infrastructure and information security, especially in e-health, limiting the adoption of 4IR technologies in the health sector. Health practitioners and patients feared the security of medical records even with the assurance that blockchain technology could guarantee better security. Figure 5 shows some factors influencing the use of 4IR technologies for sustainable development in Africa.

## 6. Discussion of the findings

The findings showed an increase in the number of publications on 4IR in Africa. According to Mayer *et al.* (2021), 4IR technologies disrupted how people work and deliver services. This has aroused the interest of many scholars who are now investigating diverse elements of the technologies, particularly with relevance to sustainable development. Most of the research has been published in journals. This can be attributed to the policies held by many academic




**Source(s):** Authors work

**Figure 5.**
Factors influencing the use of 4IR technologies for sustainable development

institutions regarding where to publish research works and the weight journal articles have regarding research excellence (Kwanya *et al.*, 2021). In terms of the themes of the study, the findings indicated that most articles exhibited diverse themes of 4IR technologies. However, the majority of the research had been done in South Africa. It was also discernible that most of the 4IR research was done in the education sector. This may be attributed to the growth in the education sector. This growth is driven by the effort by most countries to attain SDG 4 on enhancing the quality of education (Gleason, 2018; Kayembe and Nel, 2019).

The findings indicated that African countries are trying to tap 4IR technologies and are currently aware of their potential for sustainable development. According to Wakelin-Theron (2021), the world has changed how people do their work with the introduction of 4IR technologies. 4IR technologies are acknowledged as the potential ignition that will fuel the attainment of SDGs in many developing countries in Africa. One of the areas in African countries that have applied 4IR technologies in development includes the efforts to attain SDG 3 on good health and well-being. African countries are using AI to assist in curbing diseases like cancer. 4IR technologies are also used to help people to manage mental well-being through having secure working cyberspaces (Adeoye *et al.*, 2022). 4IR technologies have also been used to enhance education (SDG 4 quality education) by supporting blended learning, especially during the COVID-19 era (Mhlanga, 2021a, b). Similarly, the findings indicate that 4IR technologies have been used to support the attainment of SDG 9 on industry, innovation and infrastructure (Ebekozien and Aigbavboa, 2021).

Although 4IR technologies have great potential for sustainable development, several factors inhibit its full realisation in Africa. Lack of an adequate policy and regulatory framework, poor infrastructure, lack of capital, information insecurity, lack of skills and inadequate stakeholder involvement are some factors hindering the adoption of 4IR technologies in Africa. These findings concur with studies by Malik *et al.* (2022), Moyo (2022),

and Simbanegavi (2019). The findings also yielded one policy brief, an indicator of some effort by African countries to formulate policy to mainstream 4IR technologies in their sphere.

## 7. Conclusion

This paper reveals many research papers on 4IR. The cleaned data had 914 publications on 4IR for sustainable development in Africa published between 2012 and 2022, with exponential growth experienced from 2014. These publications cover diverse perspectives on technology. However, the most popular themes in the publications revolve around 4IR in South Africa. Being one of the most developed economies on the continent, South Africa is prominent because it has adopted 4IR technologies the most. Of the 914 publications, 371(41%) had been authored by a single author. Therefore, this study concludes that the quantity of research output on 4IR is substantial. However, the quality of the output is relatively low. More than half of the 914 publications are yet to be cited. From the literature reviewed, it emerged that citizens of African countries are aware of the 4IR technologies and their potential for sustainable development. It also emerged that some 4IR technologies have already been used to support sustainable development initiatives in Africa. This, however, was limited to just a few countries. The sectors in which 4IR technologies have been applied include health, information management, education, construction and job creation. The literature also indicated that 4IR technologies have improved human resource management and leadership governance.

This study concludes that 4IR technologies are emerging tools that African countries need to harness to support their efforts toward sustainable development. Unfortunately, most African countries still need help adopting and implementing these technologies. The minimal application of technologies in diverse sectors of the economy evidences this. Nonetheless, it is worth noting that different countries have made some effort to apply the technologies despite myriad challenges. In such cases, good results have been observed. These are indicators of the potential of 4IR technologies in igniting and sustaining development efforts in Africa. To fully harness this potential, African countries should address their policy, infrastructure and human capital challenges through concerted and comprehensive efforts.

## 8. Recommendations

Based on the findings of the study, the authors recommend as follows:

(1) *Capacity building*: 4IR technologies come with the need for new skills. Governments in Africa should invest in education and re-skilling of their people to ensure that the new technologies do not lead to retrenchments but improve productivity. The governments can partner with academia to ensure that graduates enter the job market with the relevant skills for harnessing 4IR technologies.

(2) *Policy making for 4IR*: There is a need for the African governments to explore the potential impact of 4IR on SDGs and develop requisite policies and regulatory frameworks and create a conducive environment for harnessing 4IR technologies for sustainable development.

(3) *ICT infrastructure*: African countries should work towards upgrading their ICT infrastructure. This can be done by accelerating the rate of physical and digital connections.

(4) *Scale up stakeholder involvement in 4IR*: Involving both the private and public sectors in understating the benefits of 4IR for sustainable development is crucial. This is because they play critical roles in facilitating the use of these technologies in supporting development initiatives.

## 9. Limitations of the study

This study relied on bibliometrics approaches and a literature review to examine the awareness, perception and application of 4IR technologies. Therefore, it is limited regarding the actual reality on the ground. There is a need for empirical studies to ascertain the status of applying 4IR in sustainable development in Africa.

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**Corresponding author**
Lucy Kibe can be contacted at: kibelucy871@gmail.com