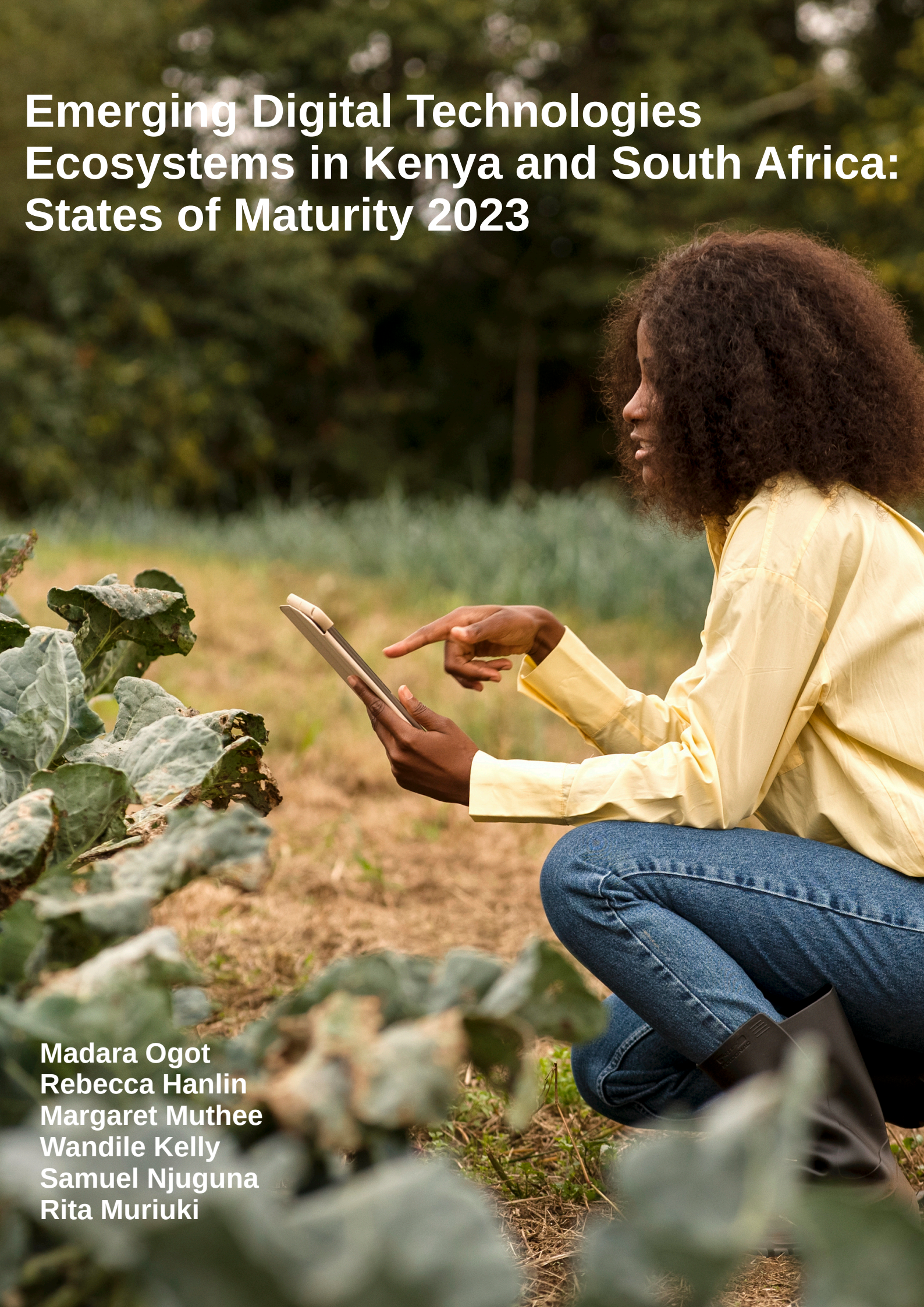
Emerging Digital Technologies Ecosystems in Kenya and South Africa: States of Maturity 2023



Madara Ogot
Rebecca Hanlin
Margaret Muthee
Wandile Kelly
Samuel Njuguna
Rita Muriuki

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Prof Madara Ogot
Rita Muriuki
University of Nairobi
KENYA

Prof Rebecca Hanlin
Wandile Kelly
University of Johannesburg
SOUTH AFRICA

Margaret Muthee
Samuel Njuguna
NACOSTI
KENYA

University of Nairobi | University of Johannesburg

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1 INTRODUCTION

1.1 Background Information

Data generation is growing exponentially, driven by the rapid increase in devices such as mobile phones, computers, sensors, etc., connected to the Internet and thus to databases. The new data sources and technologies (e.g. machine learning algorithms) "can identify patterns in observed data, build explanatory models, and make predictions quicker and with more accuracy than humans".[1] Emerging digital technologies (EDT) and X-Data-based applications, for example, have been used to develop mitigation measures against Malaria, Zika, and Dengue Fever in India, identify lower-priced generic drugs in South Africa (SA)[2] and tackle flooding in Indonesia.[3] However, these algorithms are mainly created in developed countries and often lack transparency arising from intellectual property rights, thus hindering the realisation of the enormous potential EDT/X-Data-based applications have in addressing socio-economic challenges faced by developing countries, where data literacy levels are also often insufficient to leverage on data-driven approaches fully.[4] In addition, where applications do exist, they are often not broadly accessible, especially for vulnerable and marginalised groups and persons with disabilities in areas with slow internet connections.

This study unpacks the generic term "big data" into four overlapping categories of data: big data, open data, user-generated data and real-time data, and collectively refers to them as "X-Data". Reaping the full benefits of X-Data requires the development of supportive systems, including more approaches to collect, aggregate, analyse, and visualise data, as well as building the capacity of communities involved in data generation, governance, and usage.[5] Such systems are often limited or absent in developing countries, thus creating new digital divides between developing and developed countries. Whereas the access to technology gap is narrowing, gaps in social integration and the impact of technology are increasing.[6] Further, barriers persist in the use and uptake of X-Data by decision-makers, including competing data sources, quality of data, limited awareness of data existence, and inadequate transformation of data into useful information or tailoring it to match decision-makers needs.[7]

EDT are often used together and include artificial intelligence (AI), blockchain, Geographic Information Systems (GIS), Internet of Things (IoT), and big data analytics. AI includes systems, techniques and methods that incorporate human-level intelligence at much faster speeds, for example, data mining (including artificial neural networks, Bayesian networks and support vector machines), machine learning, natural language processing, computer vision, and expert systems.[8] Collectively, they provide enhanced data analytics, better decision-making, and improved predictive analysis.

Kenya and South Africa have for the past few years ranked high in Sub-Saharan Africa (Kenya: 4/41 in 2020 and 3/41 in 2021 and 2022; and South Africa: 2/41 in 2020, 2021 and 2022) and reasonably well globally (Kenya: 71/172 in 2020, 78/160 in 2021 and 90/181 2022; and South Africa: 58/172 in 2020, 68/160 in 2021 and 68/181 in 2022) on the Government AI Readiness Index.[9] The index evaluates how ready a government is to implement AI in delivering public services. However, the Sub-Saharan African countries have the lowest average scores on households with internet access and the cost of the cheapest internet-enabled device relative to Gross Domestic Product (GDP) per capita.[10]

A definition of GIS is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show different data types on one map, such as streets, buildings, and vegetation, enabling easier visualisation, analysis, and understanding of patterns and relationships.[11] The hardware and software systems incorporate many data types, including cartographic, photographic and digital data.

Big data combines structured, semi-structured and unstructured data collected by organisations. Big data analytics mines this data for information for machine learning projects, predictive modelling, and other advanced analytic applications to create value. Characteristics include great variety, high volume and the need for faster processing times. Blockchains are decentralised databases that permanently, without third parties, record user transactions. The transactions are cryptographically chained (thus cannot be altered) and shared with the linked users.

A definition of IoT is a network of things embedded with sensors, software, and other technologies. They connect and exchange data with other devices and systems through the Internet. Using low-cost computing, the internet cloud, big data analytics and mobile technologies, physical objects (ranging from everyday household appliances to complex industrial applications) can share and collect data with minimal human intervention.

This study aimed to take a deep dive into and assess the maturity level of the EDT ecosystems in Kenya and South Africa, focussing on their applications in the context of X-Data. It builds upon the United Kingdom (UK), Foreign Commonwealth Development Organization (FCDO) – Funded project; *Emerging technologies in Kenya and South Africa - A Landscape Analysis.*[12]

1.2 Methodology

The approach involved an in-depth literature review, a review of the policy and regulatory environment, stakeholder engagement through interviews/surveys, and an assessment of the maturity of the emerging digital technologies ecosystem in Kenya and South Africa. The literature review followed a multi-vocal systematic approach[13] of both peer-reviewed academic articles and grey literature covering the development and use of EDT in Kenya. The grey literature reviewed focussed on reports, trade journals, technical papers, books and book chapters. The governance frameworks, embodied in policies, laws, and regulations relevant to EDT and arising from the literature review, were identified and synthesised, providing an overview of the regulatory and policy environment.

Maturity or development stage models of an ecosystem provide tools for assessment of where an ecosystem is in its life cycle. They provide insights into the status of recognised success

[1] Wesolowski et al (2013)
[2] Wesolowski et al (2013)
[3] openup.org.za
[4] petajakarta.org
[5] Joubert et al (2021)
[6] GIZ (2014)
[7] Wesolowski et al (2013)
[8] Mgala, M. (2020)
[9] openup.org.za
[10] National Geographic Society, www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/
[11] petajakarta.org
[12] Madara et al., (2022); Hanlin et al., (2022)
[13] Joubert et al (2021)

Table 1.1. Relationship between Fundamental Activities, Primary, Secondary Actors and Institutions

Fundamental Activities	Primary Actors	Secondary Actors
Education (knowledge and graduates) *Research* (basic, developmental and engineering) *Implementation* (production and commercialisation) *End-Use* (customers of the product or process outputs) *Linkages* (bringing together complementary knowledge)	Organisations that perform one or more of the five fundamental activities.	Organisations that directly affect the behaviour of or action between primary actors (e.g., through mandates, regulations) or indirectly (e.g., through policies, incentives.) Institutions These are practices, rules or organisations that guide or constrain actors' behaviour.

Developed from Liu and White (2001)

factors essential for the ecosystem's maturity, health, and sustainability. For example, the Ecosystems Connections Mapping Project developed a model to establish the development stage of localised start-up ecosystems. It defined three development stages (nascent, advancing, and mature) based on measurable metrics linked to the dimensions of community, skills, supporting infrastructure, investment, and constraints. The World Bank used the methodology to assess the development stages of start-up ecosystems in several cities, including Bogata, Dar es Salaam, Cairo, London, New York, and Singapore.[14] The International Telecommunications Union developed an ecosystem maturity model whose development stages followed the entrepreneurship cycle: pre-idea and culture, ideation, start-up, valley of death, and SME. These stages are evaluated based on five dimensions corresponding to critical stakeholders: entrepreneurs, finance, support, corporate, academia, and government.[15] A maturity model for software start-up ecosystems was developed with four development stages: nascent, evolving, mature, and self-sustaining.[16] These stages are assessed along eight dimensions: existing strategies, entrepreneurship universities, angel funding, culture values for entrepreneurship, specialised media, ecosystem data and research, ecosystem generations and events. These models, however, do not adequately capture the peculiarities nor properly define the stages of maturity of EDT. An emerging technologies ecosystem maturity model developed by Ogot et al.[17] was used for this study. A brief description of the model follows.

1.3 Emerging Technology Maturity Model

The emerging technologies maturity model is based on the five fundamental activities of the innovation processes framework.[18] The activities—*education, research* (basic developmental, engineering), *implementation* (manufacturing, deployment), *end-use* (customers of the product or process), and *linkages* (bringing together complementary knowledge)—are performed or supported by primary and secondary actors and institutions. Collectively, they form the critical elements of an innovation system. Table 1.1 presents their relationships.

Education focuses on the university level Higher Education Institutions (HEIs) that provide the ecosystem with a continuous stream of new knowledge (for example, publications and patents) and new carriers of knowledge (students). They create "qualified personnel [in the ETs] who can monitor technological and other trends, assess their relevance to the prospects for the country and individual firms, and help to develop a strategy for reacting to and taking advantage of those trends".[19] On the other hand, research embodies basic research carried out by universities and research institutes. (Universities, research institutes, and industry conduct research development, while industry mainly *performs engineering research). End-use* embodies the final consumers of the developed products and services and ranges from individual consumers to society. Their strong and visible changes in preferences influence the setting of Research and development (R&D) priorities and technological change direction.

Linkages between the actors are essential for successful innovation, diffusion, and exploitation (Liu and White, 2001). However, effective connections within innovation systems still need to be improved in developing countries, including Kenya. Finally, *implementation* involves the conversion of research (knowledge) using linkages (networks) and end-use (markets) to exploit new business opportunities. The key actors are the entrepreneurs, the start-ups, and existing businesses (diversifying their business strategy to take advantage of new developments and opportunities). New technologies often only compete with existing entrenched technologies if they are disruptive. Consequently, organisations must implement strategies to support their diffusion into the market.

Primary actors are the organisations that perform one or more of the five fundamental activities, including governments, universities, research institutes, and private enterprises. They also include bridging institutions that act as intermediaries (linkages) between the different actors, for example, research councils and associations linking research organisations and government,[20] science and technology parks, incubators and accelerators. *Secondary actors* are mainly relevant government ministries/departments/agencies (MDAs) and funding institutions. Their actions include enacting facilitative foreign direct investment policies, ensuring substantial intellectual property rights to provide an incentive for multinational

[14] World Bank (2017)
[15] GIZ (2014)
[16] Cuiker (2017)
[17] Ogot et al., (2022); Hanlin et al., (2022)
[18] Wesolowski et al (2013)
[19] Ogot et al (2022); Hanlin et al (2022)
[20] Feinson (2003)

Table 1.2: Indicators Used to Assess the State of Maturity of Each Category of Fundamental Activities

Fundamental Activities	Indicators
Education	Quality of graduates (measured by quality or availability of hires), New Masters and PhDs, university post-graduate programmes, researchers/professionals engaged in R&D, Africa/global ranking of universities with post-graduate relevant programmes, policies.
Research	Related Publications, R&D projects, patents, availability of funding for R&D, pilot projects, availability of required equipment, policies
End-use	Government targets, industry targets, demand from government, demand/opportunities in the market, demand/opportunities beyond the borders, policies
Linkages	Technology-dedicated workshops and conferences, network size, network intensity, collaboration with academia (or with the private sector), a functional observatory/repository/database of researchers, innovators, innovations and investors.
Implementation	New entrants, diversification activities of incumbents; availability of funding (traditional, equity, venture capitalists, angel investors), industry, interest groups, policies

Source: Ogot et al. (2023)

companies to conduct research locally;[21] directly funding research and financing utilisation of the research outputs; and establishing a favourable regulatory environment.[22] Funding institutions, including banks, equity funds, venture capitalists, and angel investors, support implementation activities. Finally, *institutions* capture the norms, rules and environment that influence the decisions and actions of system actors.[23] They include the political establishment, for example, parliament and the judiciary, which determine the extent to which democratic governance or the tolerance for and the nurturing of a culture of corruption, both of which can serve as barriers or enablers to innovation.[24] Table 1.2 presents indicators for each of the fundamental activities.

The emerging technologies maturity model defines three developmental stages: ideation, nascent, and growth as the final stage. A mature development stage, typical in other maturity models, is absent as a stage of maturity implies that the technology is no longer emerging. The *ideation stage* is beyond basic research and testing fundamental principles. It includes R&D activities with pilots and proof-of-concepts performed on potential commercial applications. The *nascent stage* embodies the early development and formation of the ecosystem. Characteristics include extreme ambiguity driven by technological uncertainties, competition, structures and demands. There is generally still a lack of governance structures and clear guidance on value propositions (the value to create, who to create it for, and how to create it) as well as the systems for value creation and value capture;[25] Commercial ventures have been formed, and sales have begun. Finally, in the *growth stage*, the commercial applications of the technology start gaining strong acceptance in the market with increased demand and new entrants, and the ecosystem governance structures are becoming more evident. Table 1.3 presents' indicators metrics for the three maturity stages.

Detailed stakeholder mapping of the emerging digital technologies actors in both countries, previously performed in an earlier project,[26] were updated. Questionnaires were developed and sent to a sample of two groups of stakeholders in each country: (a) researchers and innovators and (b) policymakers, funders, and decision-makers. Copies of the questionnaires are in Appendix A and B. The questionnaires were mainly composed of Likert-Scale type questions with a few open-ended questions. For the latter, analyses of the responses employed qualitative content analysis (QCA), defined as "qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings."[27] It is inductive, "grounding the examination of topics and themes, as well as inferences drawn from them, in the data."[28] and is based on the grounded theory approach. The focus, therefore, is to determine unique themes that can illustrate a range of interpretations of the issue at hand. Using QCA provides good contrast and directly complements the quantitative approach used in the first half of the questionnaire, where the interventions for interrogation were predetermined. QCA extracts the proposed interventions from the stakeholder's responses.

The analysis used emergent themes as the unit of measure. These were expressed by a few words, phrases or whole paragraphs. The key focus was the expression of an idea. Development of the themes from the responses used the constant comparative method that involved the systematic comparison of text assigned to a theme with the text already assigned to it to ensure consistency and to understand the theoretical properties of the category better. These were captured and continually updated in a coding table. The responses were analysed several times to ensure accuracy and completeness. The themes were changed, and the coding table was updated accordingly when necessary.

The collected primary and secondary data formed the basis for assessing the maturity levels of the emerging digital technologies ecosystems in both countries.

[21] Ibid
[22] Smith and Sharmistha (2010)
[23] Lundvall et al (2006)
[24] Cukier (2017)
[25] Ogot et al. (2023)
[26] Ogot et. (2022); Hanlin et al., (2022)
[27] Patton, M.Q. (2002)
[28] Zhang, Y. and Wildemuth, B. (Unpublished)

Table 1.3: Stages of Maturity in the Emerging Technology Ecosystems System

Fundamental Activities	Ideation Stage	Nascent Stage	Growth Stage
Education	• Few Masters and PhDs • A small number of academic departments • A small number of researchers engaged in related research	• Increased number of Masters and PhDs • A small number of academic departments • An increasing number of researchers involved in related research	• A large number of Masters and PhDs • Increased number of academic departments • An increasing number of researchers engaged in related research
Research	• Few or no patents, • A small number of publications • Few pilot projects, • Low research funding • Few policies supporting related research	• Increased number of patents • increased number of publications • Increased number of pilot projects • Moderate research funding • Strengthened policies supporting related research	• Increased number of patents • A large number of publications • A large number of pilot projects • Adequate research funding • Strengthened policies supporting related research
End-use	• Insufficient demand and information for potential products and services, market size	• Better understanding of and increasing demand for potential products and services, market size	• Good understanding of and robust demand for potential products and services, increased demand for industrial product development through research, market size
Linkages	(a) None or few international connections (research) (b) Few linkages (c) No clusters	(d) A small number of international connections (research and business) (e) A small number of linkages (f) A few clusters	(g) Moderate international links (research and industry) (h) Moderate linkages (i) Moderate clustering (j) Moderate academia-industry linkages
Implementation	• Negligible active start-ups or existing businesses who have diversified into the ET space	(k) A few active start-ups or existing businesses have diversified into the ETs space but are in the early stages. (l) None or very few start-ups exist (m) Establishment of governance framework (n) Gaps in financing	(o) Moderate number of active start-ups or existing businesses that have diversified into the ET space (p) A moderate number of start-ups (q) Facilitative governance framework (r) Increasing private-sector financing

Source: Ogot et al. (2023)

2. MATURITY OF THE EMERGING DIGITAL TECHNOLOGIES ECOSYSTEM IN KENYA

2.1 Introduction

The following sections discuss the level and details of the primary and secondary actors' activity in Kenya's emerging digital technologies ecosystem. Their assessment provided insight into the maturity level of the ecosystem.

2.2 Primary Actors

Perspectives were obtained from twenty-five researchers and innovators from across Kenya to supplement the collected secondary data. They included members from the private and public sectors, with 52% from academia, 20% from research institutions and 28% from the private sector. The participants included research scientists (24%), lecturers (24%), ICT and innovation directors (16%), and data analysts (8%) among others. Further, 88% of the participants were male, and only 12% were female. These proportions reveal the prevailing gender disparities in the ecosystem.

All participants had post-graduate degrees, with 72% of the respondents having a Master's degree as the highest academic qualification and 28% having a PhD. Further, the participants possessed varied levels of experience in academia or research, ranging from below 5 to 25 years, specifically, 8% with over 15 years of experience in academia and research, 48% with between 6 to 15 years of experience, and 44% with below five years of experience. The following sections present the secondary data analysis and the primary actors' perspectives.

Education

The percentage of universities offering undergraduate EDT-related programmes (excluding GIS, whose programmes are separate) was 52.4%. The programmes produce an excellent

human resource for developing products and services based on current technologies. The EDT-related programmes dramatically dropped at the Masters level and fell further for Ph.D. programmes, where only 12.7% and 6.3% of the universities offered related programmes. As a result, the country remains weak in developing new EDT, typically undertaken by Masters and PhD students and graduates. For GIS, the proportion of universities offering related undergraduate programmes was 11.1%, with only 6.3% and 3.2% offering the programmes at Masters and PhD levels, respectively.[29] Therefore, there needs to be a more robust human resource pipeline supporting local research and development of GIS-related applications.

Primary data analysis from a sample of researchers and innovators revealed that 56% had undertaken various courses and training on EDT and X-Data (see Table 2.1). Such undertakings are essential in building capacity and enhancing experts' potential in the ecosystem.

Table 2.1: EDT/X-Data-Related Courses Attended by Surveyed Researchers and Innovators in Kenya

Course	No. of participants	Percent
Big data and analytics	7	50%
Internet of Things	3	21%
Artificial Intelligence	2	14%
GIS	2	14%
Cloud Computing	1	7%
Open data	1	7%
Machine learning	1	7%
Innovation Sandbox	1	7%

TVET institutions train hands-on workers for industry, and their students produce many innovative products. Many innovations come from industry, emanating from solving production and process challenges.[30]. TVETS significantly contribute to innovation by prototyping and designing innovative products. Their teaching methods that combine knowledge and skills are very effective in innovation development, key to the exploitation of EDT[31]. Innovations include the solar-powered vehicle with a mobile application to detect obstacles and prevent accidents from Nyeri National Polytechnic and smart water meters by Eldoret National Polytechnic, among others. TVETs have other innovations that can be enhanced using EDT, including solar desalination machines, irrigation pumps and systems, driers and cookers.

TVET institutions have a critical role in innovation development and implementation processes by acting as mechanisms of skills formation and diffusion. Developing and implementing vocational curricula are some of the most fundamental activities in TVET systems, especially considering the recent impacts of new technologies related to industrial automation or the changes in working environments and practices.[32]

Poor performance in the Kenya Certificate of Primary Education (KCPE) exams often serves as a strong indicator of those students not meeting their career aspirations. AI tools were used to identify students who needed intervention to improve their KCPE exam performance two years before the exam. Based on student records, the intervention prediction models in the pilot study were relatively accurate in enabling educators to take appropriate measures early enough.[33] IBM Research Africa has been working with RTI International to use AI, cognitive and mobile technologies targeting schools where students have a high risk of failure. The initiative captures data, including class size, grades, and school resources, to propose various interventions. IBM is also exploring AI technology that can support students in Nairobi to personalise their learning experience.[34]

Research

The recent entrance of multi-national and development partners in R&D centres has increased research actors. The centres are tapping into local expertise to conduct contextualised R&D while acting as nodes within their global R&D activities. For example, the Microsoft Africa Development Centre (in Nairobi since 2019) is working on software engineering, machine learning, data science, market research, and ICT infrastructure. IBM Research Africa, anchored in Kenya and South Africa, is an industrial research facility that seeks to "drive innovation by developing commercially viable solutions to transform lives and spark new business opportunities." Their digital products, based on AI, blockchain, and data analytics (among others), support water, agriculture, transportation, healthcare, financial inclusion, education, energy, security and e-government businesses.

Despite the apparent growth in EDT applications in Kenya, the absence of significant R&D has resulted in most deployed applications relying on non-African technologies. As a result, they often lack contextual relevance, especially about aspects of culture and infrastructure (Oxford Insights and IDRC, 2019). The main areas of EDT research were agricultural, conservation, education, fintech, governance, and health sectors. For example, of the surveyed stakeholders, 48% worked in agriculture, another 28% in health and the remaining 12% in governance (see Table 2.2).

The study participants' research touched on all the stages of development from *Just Starting* to *Ready for Deployment/Commercialisation* or *Publication* (see Figure 2.1). Although 32% indicated they would likely file for a patent or copyright in the next year, none had previously filed one. Examples of EDT/X-data research and innovations from various sectors follow.

Agriculture

The Kenya Marine and Fisheries Research Institute has been working with international partners to use unmanned aerial systems (drones), high-resolution satellite imagery, and Geographic Information Systems (GIS) to map the spread of tilapia cages on the Kenya part of Lake Victoria. This data-

[29] Ganter de Otero, Jan Peter (2019)
[30] openup.org.za
[31] Ganter de Otero, Jan Peter, 2019, Innovation in TVET: UNESCO-UNEVOC Trends Mapping. UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training
[32] National Geographic Society, www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/
[33] petajakarta.org
[34] Ogot et al., 2022; Hanlin et al., 2022.

intensive system provides spatial and change detection, yielding a deeper understanding of the impacts of growth in commercial fish cage culture.[35]

Table 2.2: Sectors Targeted by Surveyed EDT/X-Data Researchers and Innovators in Kenya

Sector	No.	Percent
Agriculture	12	48%
Health	7	28%
Governance	3	12%
Creative arts	1	4%
Marketing	1	4%
Cities	1	4%
Conservation	1	4%
Cyberspace	1	4%
Fisheries and Aquaculture	1	4%
Livelihoods	1	4%
Safety and Security	1	4%
Transport	1	4%

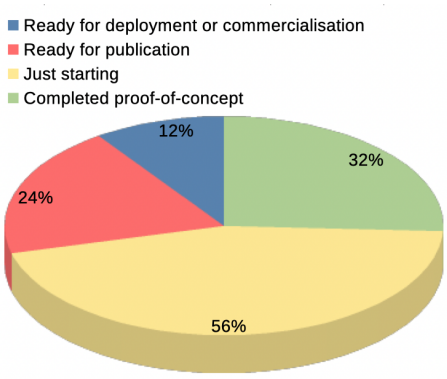


Figure 2.1: Stage of Current EDT/X-Data Research Activities of Surveyed EDT/X-Data Researchers and Innovators in Kenya

The Kenya Agricultural and Livestock Research Organization (KALRO), through the Kenya Climate-Smart Agriculture Project (KCSAP) and the National Agricultural and Rural Inclusive Growth Project, has established a big data platform to transform the agriculture and food system in the country. The platform has enabled KALRO to integrate agro-weather data, market data, and farmer data to provide customised geospatial and timely agro-weather and market information to farmers and policymakers[36].

Conservation

Researchers at Dedan Kimathi University have created a camera trap data set of six wildlife species captured in a conservancy in Nyeri. Zoologists, ecologists and researchers use camera traps to acquire wild animal images non-intrusively for ecological and conservation research. The dataset that has been made globally available has over 10 thousand images.[37]

Governance

Hate speech propagated over social media platforms through text messages, pictures, videos, emojis, etc., is becoming a big problem worldwide, often with deadly consequences. Hate speech distributed over social media is more challenging than traditional media (for example, newspapers, TV, and radio) as it can be quickly produced and distributed anonymously at a low cost, potentially reaching a global audience in real time. Researchers in Kenya have been working on AI models that can detect political hate speech propagated over social media platforms.[38]

Health

Inadequate access to microscopy diagnostics remains a problem in limited resource settings, which impedes diagnosing and treating common and treatable conditions. Digital microscopy and artificial intelligence using deep learning present opportunities to address these challenges.[39] A team of researchers conducted a pilot study in Kinondo to establish whether point-of-care digital microscopy and AI-based assessment of samples (through image and signal processing) can analyse cervical cancer test results. Cervical cancer is highly preventable yet remains a common and deadly disease in areas without screening programmes due to a lack of pathologists. Their AI-supported approach was able to detect atypical cervical smears with the same high sensitivity as a visual analysis done by a pathologist.[40] IBM Research Africa is developing computational platforms and tools (for example, understanding natural language and images, bioinformatics) enabling the mining of biological and medical data to transform the prevention, diagnosis, treatment and management of disease, with a current focus on tuberculosis and HIV.[41]

The Kenya Health Management Information System (KHMIS) project develops and maintains an integrated National Data Warehouse (NDW) for anonymised patient-level data. The NDW acts as a repository and analytics platform through the connection, collation, and aggregation of patient data from all electronic medical records in the country[42]. It hosts de-identified data to facilitate programmatic monitoring of Health Information System implementations and progress on clinical care and outcomes for HIV-infected and exposed persons. Also,researchers at Jomo Kenyatta University of Agriculture and Technology are researching data analytics, specifically incorporating data visualisation to develop techniques to strengthen healthcare insurance management. The approach can provide deeper insights into healthcare insurance data by revealing previously undetected data integrity issues, cost management pointers, case management insights and scheme performance, thereby guiding premium entitlement and ailment cost burden management.[43]

Primary data from surveyed researchers and innovators revealed that machine learning is the most commonly used EDT (44%), followed by AI (24%), as shown in Figure 2.2. Also, the

[35] Hamilton et al. (2020)
[36] https://olc.worldbank.org/print/content/digital-ag-series-big-data-platform-scaling-data-driven-digital-agriculture-learnings-kenya
[37] https://www.sciencedirect.com/science/article/pii/S2352340922010666
[38] Mahony et al., 2019
[39] Beck, H.P., 2022
[40] Holmstrom et al (2021)
[41] Ganter de Otero, Jan Peter (2019)
[42] https://kenyahmis.org/documentation/summary-national-data-warehouse/
[43] https://www.jkuat.ac.ke/big-data-poised-to-revolutionise-healthcare-industry/

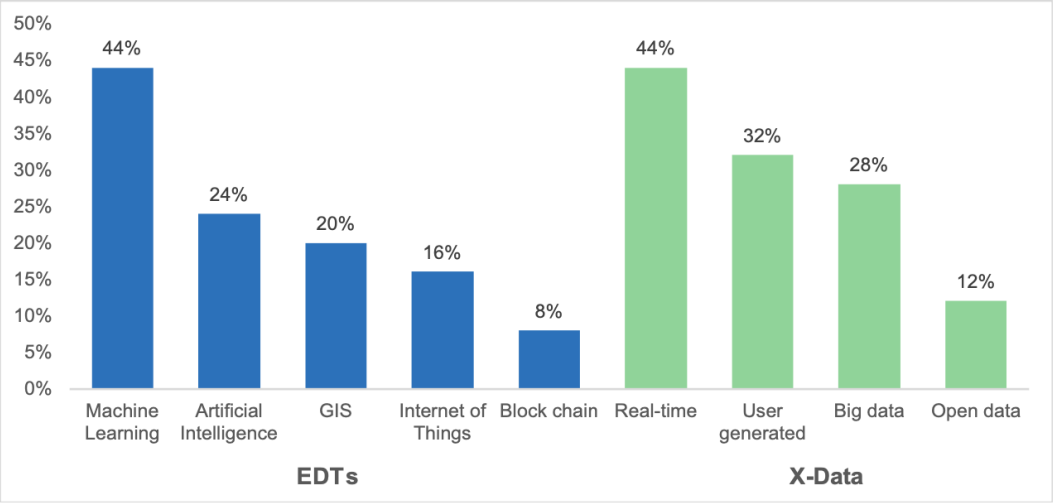


Figure 2.2: Percent of Surveyed Researchers and Innovators in Kenya using different types of EDT/ X-Data

most frequently used data source is real-time data (44%), followed by user-generated data (32%).

Journal publications are critical research outputs in disseminating research findings and knowledge transfer. Table 2.3 presents journal publications output related to EDT/X-Data from our participants. 56% of the them had published their research outputs in journals with the distributions shown therein.

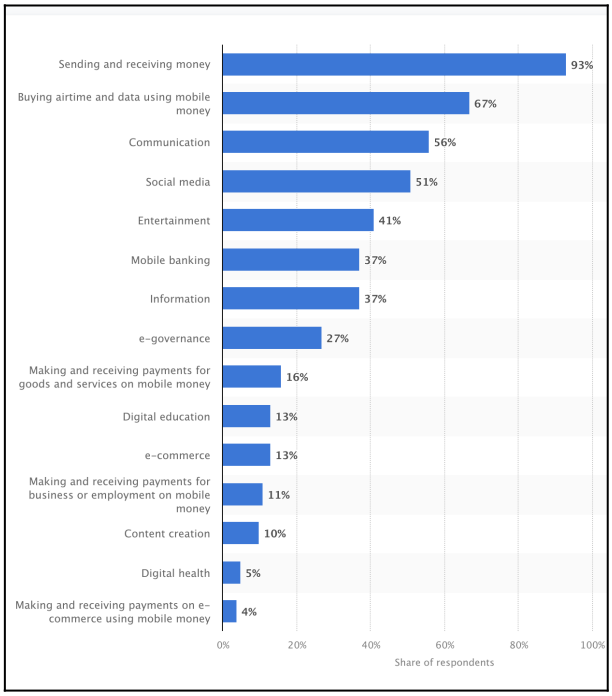
Researchers and Innovator participants were asked to state three challenges they faced. The QCA analysis revealed four emergent themes: Inadequate resources, data, researchers and innovator aspects, and commercialisation. Table 2.4 presents a description of each of the themes that emerged, sample quotations from the respondents, thereby placing the derived theme in a better context, when the coding was used and how many times different respondents proposed the themes. Areas submitted by only one respondent were omitted. The themes provided suggestions for possible intervention areas to strengthen the EDT/X-Data ecosystem. Overwhelming, the main challenge faced by researchers and innovators was inadequate resources, specifically computational and financial resources.

Table 2.3: Number of publications Directly Related to EDT/X-Data by Surveyed Researchers and Innovators in Kenya

No. of publications	No. of Researchers	Percent
0	11	44%
1	6	24%
2	1	4%
3	2	8%
4	1	4%
5	3	12%
6	1	4%

End Users

By March 31, 2023, internet subscriptions in Kenya stood at 47.96 million, out of which 67.1% were on mobile broadband[44]. There were 66.1 million mobile (SIM) subscriptions, translating to a mobile (SIM) penetration rate of 130.5% (greater than 100% as many people had more than one SIM). Mobile money subscriptions stood at 38.4 million, translating to a penetration rate of 76%. At the same time, the number of mobile devices was 62.96 million, translating to a device penetration rate of 124.5%. The penetration rate for feature phones and smartphones was 66.2% and 58.3%, respectively. Although there is a low gender gap in mobile usage, a significant gap persists in Internet usage. Mobile money services, led by *M-Pesa*, have driven high mobile use by both men and women and have significantly increased financial inclusion. The mobile gender gap stands at only 6%.



Source: Statistica data for 2020, viewed May 2023

Figure 2.3. What is the Kenya Digital Citizen Doing?

[44] https://www.ca.go.ke/mobile-subscriptions-hit-66m-march-2023

Table 2.4: Challenges Faced by Surveyed Researchers and Innovators in Kenya in the EDT/X-Data Ecosystem

Area (Frequency)	Description	When Used	Sample Quotes
Emergent Theme 1: Inadequate Resources			
Computational resources (6)	Appropriate required computational resources	All references to the lack of or need for better computational resources, including access to High-Performance Computing.	"Limited High-Performance Computing (HPC) resources -- Some X-Data analyses require HPC resources. Such resources are available as SaaS and limited in terms of accessibility time."
Research funds (5)	Funding for research in EDT and X-Data	All references to inadequate funding or few sources of funding	
Lack of adequate research equipment (2)	Availability of equipment used for EDT/X-Data research.	All references to not having the right equipment needed for the desired research.	
Emergent Theme 2: Data			
Access to/availability of Big data (4)	Ability to access Big Data from other organisations	All references to the inability to access or the unavailability of required data.	"Restrictions on accessing X-Data held by some organisations"
Data Analysis (2)	Ability to analyse the collected or retrieved data	All references to challenges faced in analysing available data.	"The use of appropriate tools in exploring the data"
Data Protection (2)	Protection of the data collected	All references to data protection, ethics of data collected and privacy.	"Data protection, data verification"
Emergent Theme 3: Researchers and Innovators Aspects			
Specialised training beyond degrees (3)	Training in EDT or X-Data beyond topics covered in university	All references to lack of skills or training required for certain aspects of research.	"Inadequate training and knowledge ... Lack of sufficient exposure"
Time constraints (2)	Enough time is available to carry out research.	All references to time pressures from other activities limiting time for research.	"Time for research versus other duties"
Collaborators (2)	Collaborating with others on research	All references to working with collaborators or forming collaborations challenges.	"Challenges in convincing industrial players to collaborate in X-Data research."
Emergent Theme 4: Commercialisation			
Intellectual property protection/commercialisation (2)	From IP protection to commercialisation.	All references to protecting IP and commercialising the research output challenges.	

The Internet usage gap between men and women is much higher at 38%.[45] The digital gender divide presents a big challenge for women in Kenya to participate fully as digital citizens. A significant gap also exists between rural and urban areas. Estimated access to the Internet is 44% in urban areas and only 17% in rural areas. Rural communities remain largely unconnected or use only essential digital services due to affordability barriers to the required digital tools (mobile phones, Internet access, computers) and lack of basic digital skills.

Micro, Small and Medium Enterprises are often end-users of EDT but need more expertise to implement solutions that could boost their businesses. Companies such as *Fastagger* in Kenya provide them with the knowledge and solutions customised to the enterprise's needs. Specifically, they use AI- and blockchain-powered analytics to harness the potential of data to help MSMEs grow by increasing sales and loyalty. Their platforms process large amounts of data to identify customer patterns and trends that are difficult to detect manually.[46]

Finally, a study of sentiments of tweets over five years (2016-2021) on Kenya's Twitter platform relating to the use of AI to further the country's socio-economic development was largely positive, with 51.5% of the tweets on the topic positive, 49% neutral and none negative. This optimism may be due to the young EDT ecosystem in Kenya, compared to South Africa, where the development and adoption of EDT, such as AI, is more widespread and practised that the public may be past a

[45] Fastagger, fastagger.com

[46] Joubert et al. (2021)

"techno-optimism" phase as possible being experience in Kenya.[47]

Linkages

Linkages within the digital ETs ecosystem were primarily through innovation hubs, incubators, accelerators and industry associations. Examples include iHub in Nairobi, with an Open IoT programme launched in September 2020 (in partnership with GSMA Africa) as a pan-African IoT community platform, facilitating conversations supporting the growth of the African IoT ecosystem; Ibiz Africa, a business incubator that focuses on ICT solutions and based at Strathmore University; and NaiLab, an ICT incubator that provides a simplified platform providing innovators visibility and access to venture capitalists and business angels and investors.[48]

Knowledge transfer between academia and industry is an essential driver of innovation and economic growth as it eases the commercialisation of new scientific knowledge within firms.[49] Knowledge Transfer Offices (KTOs) have been established in universities to serve as innovation linkage intermediaries and facilitate transfer activities, for example, spin-off creation support, patent protection and licensing. Institutions with KTOs include Strathmore University, University of Nairobi, Dedan Kimathi University of Technology, Jomo Kenyatta University of Agriculture and Technology, Kenyatta University, Meru University of Science and Technology and the Kenya Industrial Research and Development Institute.

Industry associations are non-profit organisations with specialised knowledge and capabilities performing innovation enabler roles. They are an enabler of innovation by identifying and legitimising firms, for example, creating industry directories; facilitating the creation of inter-firm relations, for example, through networking activities; and by providing increased access to resources through network brokerage activities, for example, providing access to knowledge in universities and opportunities in foreign markets. [50]. Examples of industry associations in Kenya include the Global Innovation Society of Kenya, an association of progressive innovators with a mandate of addressing the challenges facing startups and small and medium enterprises (SMEs) in Kenya under the umbrella of Kenya Private Sector Alliance; Association of Countywide Innovation Hubs, an association of hubs located outside Nairobi, whose main objective is to promote activities and programs of the member hubs and supporting their vision of testing and building impactful sustainable businesses in rural and second tire towns of Kenya; Association of FinTechs in Kenya, driving the adoption of digital innovation as a core strategy for efficiency, scalability, and competitive positioning in the financial sector, while fostering national, regional and international cooperation in digital innovation; and the Association of Startups and SMEs Enablers of Kenya, an association that brings together and represents the interests of organisations supporting the development and growth of startups and SMEs.

Several annual conferences bring together players in the sector. These include the Connected Summit,[51] organised by the ICT Authority and the Ministry of ICT since 2009. It brings together over one thousand leaders, policymakers, industry champions and executives, financiers, ICT innovators, and related associations and networks, including the Computer Society of Kenya and the Kenya ICT Action Network[52]. The Kenya Innovation Week (KIW), now in its second year, is organised by KeNIA to provide a platform for innovators, entrepreneurs, investors and government officials to share ideas and showcase practical skills that lead to innovation and with impact on society[53]. Also, the Nairobi Innovation Week is an annual event organised by the University of Nairobi to celebrate local and international innovations, address critical issues in innovation management and build Kenya's innovation ecosystem[54]. Other universities and TVETs across the country have also organised innovation weeks to provide a platform for showcasing and networking among various actors in the ecosystem.

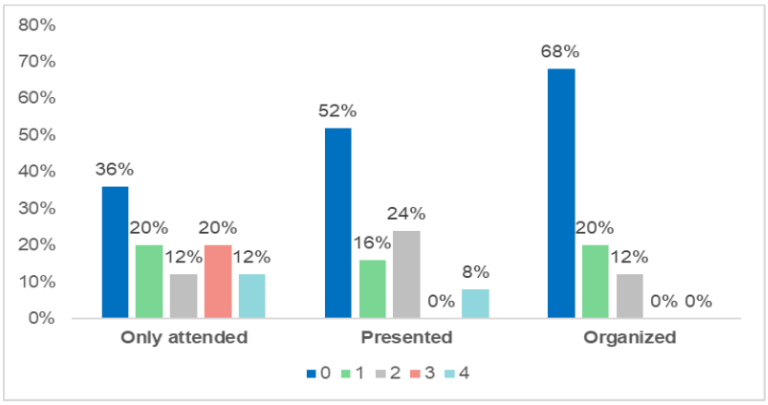


Figure 2.4: Attendance, presentation and organisation of conferences on EDT/X-Data in Kenya by Surveyed Researchers and Innovators

The survey of researchers and innovators found that they took advantage of several platforms for learning, networking and disseminating their work outputs, especially conferences attended, presented at, and organised, as shown in Figure 2.4. However, a majority of researchers had yet to attend (36%), present at (52%) or organise (68%) a conference in Kenya touching on EDT/X-Data.

Research collaboration, especially between academia and industry, presents opportunities for learning, networking, pooling of resources and pathways to commercialisation, thus strengthening the ecosystem through linkages between the actors. Of the study participants, 44% had and continue to collaborate with industry (see Table 2.5).

Implementation

With the increase in EDT, organisations must create strategies for their commercialisation. EDT innovations are disruptive and are rapidly being developed in many forms, touching on all sectors of the economy. A commercialisation strategy is needed to expound on how EDT innovators can protect their

[47] Ogot et al., (2022); Hanlin et al., (2022)
[48] Hamilton et al. (2020)
[49] Dalziel, Margaret. (2006)
[50] *Ibid*
[51] Computer Society of Kenya, cskoline.org
[52] GIZ, (2006)
[53] https://kenyainnovationweek.com
[54] https://vc4a.com/nairobi-innovation-week/

innovations, some of which are not patentable in the traditional sense due to their nature as software applications. Thus, other methods, such as data rights, licensing contracts and copyrights, are available for protection. Establishing a monetary value system to determine EDT value for licensing and contracting to investors shall prevent innovator exploitation.

Table 2.5: Research Collaborations by Surveyed EDT/X-Data Researchers and Innovators in Kenya

Type of collaboration	Researchers
Collaboration with industry in current research activities	44%
Collaboration with industry in past research activities	44%
Collaboration with other universities/research institutions in current research activities	32%
Collaboration with other universities/research institutions in past research activities	28%

The institutionalisation of an EDT commercialisation process must firmly be established in the Kenya National Innovation Agency to address the fragmented approach from various public and private sector initiatives. A framework to guide the negotiation at the time of licensing and contracting needs to be structured to avoid exploitation of innovators by investors where the EDT owner can choose to remain as a founding director in the startup, get royalties, or sell off the whole innovation. The study found implementation of EDT mainly in the agricultural, education, financial, health, manufacturing and transport sectors. Examples from each of the sectors follow.

Agriculture

Shamba Records,[55] based in Nairobi, provides several digital tools leveraging AI and Blockchain to help farmers in sub-Saharan Africa increase their yields, become more profitable, track and trace their crops, and exploit new market opportunities. For example, their real-time data collection tool collects farmer's production data, linking it to aggregation centres and the market. The company automates payments to the farmers, credit scoring, credit issuance, market linkage and agricultural extension services for the entire process. The company leverages blockchain technologies to eliminate ghost farmers and prevent manipulation of farm or harvest records. The technology also underpins smart contracts between farmers leasing land from other farmers. In 2019, more than six thousand farmers in Kenya in the coffee, tea, and dairy sectors were using the platform.

Education

Eneza Education[56] provides revision and study materials for learners 10 to 18 years old through an SMS system (for legacy phones) or a web portal. Millions of students in Kenya, Ghana and Cote d'Ivoire use the AI-based tutoring system to receive quality and inclusive education.

Financial

Developing countries are increasingly using AI to develop solutions to critical challenges, including providing financial services to under and unserved populations. Machine learning algorithms and the growth in digital users make using AI-based credit scoring possible. For example, *M-Shwari*, a product of the Kenya telecom giant Safaricom, uses machine learning algorithms to predict default rate probabilities of potential borrowers to determine who to provide small loans to and the maximum amounts. The systems use non-traditional data resident on the user's devices, including mobile phone call records, mobile money transactions data, text messages and address books. The automated processes significantly reduce the cost of providing these loans. By March 2023, the Digital Financial Services Association of Kenya (formerly Digital Lenders Association of Kenya) reported that digital lenders had disbursed over Ksh500 billion in mobile loans to individuals and small businesses.[57]

Utu Technologies is leveraging AI and blockchain to provide a trust infrastructure on the Internet, replacing current anonymous star ratings, reviews and scores. Their software and platform replace these approaches with AI-based tools that adapt to users' preferences and context, allowing businesses to provide personalised recommendations, thereby increasing conversions and sales. They use blockchain to prevent the manipulation of reviews and ratings.[58] *Pezesha* leverages AI to provide a digital lending infrastructure and marketplace that connects small and medium businesses with working capital. Their system supports alternative credit scoring and lending infrastructure as a service.[59] Similarly, *Cherehani Africa* provides credit services by leveraging mobile-based technology to provide credit and distribute personalised financial literacy content to women and adolescent girls who own micro-enterprises.[60]

Sarafu, a community inclusion currency (vouchers) developed by Grassroots Economics, a Kenyan non-profit foundation, leverages blockchain to empower marginalised communities to take charge of their livelihoods and economic futures. In 2020, for example, the "currency" was used by over forty-one thousand people in 60 villages across Kenya. They performed over 335,000 transactions using their mobile phones, equivalent to $2.5 million. Through USSD phone technology, users can access the platform without the Internet. Community inclusion currencies enable groups to come together, form their currencies and build a resilient economic system from the bottom up. In July 2023, there were over 13,000 transactions.[61]

Health

Health informatics is the acquisition, storage, retrieval and use of healthcare information to improve the care of patients during their interactions with the health system. Electronic medical records combined with AI provide opportunities to improve patient care, decision-making and public health informatics.[62] A commercialised AI and blockchain-based digital platform, *Afya AfyaRekod*[63], is premised on the notion that patients should maintain the sovereign ownership right of their health data. The electronic medical records platform allows health facilities and patients to use the data to make informed decisions, resulting in

[55] https://www.shambarecords.com
[56] https://enezaeducation.com
[57] https://www.money254.co.ke/post/kenyans-make-a-comeback-to-mobile-loans-as-inflation-continues-to-bite-money-weekly
[58] https://utu.io
[59] https://pezesha.com
[60] https://cherehani.org
[61] https://www.grassrootseconomics.org/pages/sarafu-network
[62] Lee & Kim, (2021)
[63] https://afyarekod.com

doctors providing better healthcare. The platform enables doctors to manage patients' health data in real-time and access patients' data from all health facilities they have visited. On a broader scale, anonymised data supports disease tracking and outbreak and pandemic mapping. Also, Bora, an electronic medical records system, has been used in Kenya to improve maternal and child health and HIV treatment. The 2015 pilot study found that the system helped to close critical care gaps.[64]

Manufacturing

NumeralIOT is an electronic design and manufacturing company that has developed products and services that leverage AI and IoT. They also provide electronic design and manufacturing support to other businesses. Examples of their products include 4G speed governor, vehicle tracking and security devices and cashless payment solutions.[65]

Transport

Hello Tractor, a company that started in Nigeria and is now also based in Nairobi, has developed an IoT platform to connect farm equipment owners, dealers and banks with farmers who need those services. The platform simplifies and makes fleet management more profitable. It supports every aspect of a tractor fleet, from the operators to the farmer customers, by enabling the farmer to request affordable tractor services and providing enhanced security to the owners of the tractors through remote asset tracking (using Global Positioning Systems – GPS) and virtual monitoring (fuel management, driver management, fraud reduction).[66]

The study sought the perspectives of ten policymakers and decision-makers (see Appendix B). The participants were 60% male and 40% female.

2.3 Secondary Actors

Governance Frameworks

The government has adopted an approach to EDT that protects citizens, ensures fair markets, and enforces regulations while enabling technologies and businesses to thrive. This approach embraces:[67]

(a) adaptive regulation that encourages a shift from "regulate and forget" to a responsive, interactive approach;
(b) regulatory sandboxes and accelerators for prototyping and testing of new systems;
(c) outcome-based regulations that focus on results and performance rather than form;
(d) risk-weighted regulation that moves from one-size-fits-all regulations to a data-driven, segmented approach; and
(e) collaborative regulations developed by engaging a broad set of players across the ecosystem to align national and international regulations.

The key ministries and agencies active in the ecosystem include the Ministry of ICT, Innovation and Youth Affairs, which developed and is implementing the National ICT Policy (2019). The policy provides a proactive framework to guide the orderly development of the ICT sector; the Communication Authority, among others, issued guidelines on the use of IoT devices; the Kenya Civil Aviation Authority issued regulations on the use of drones; the Central Bank of Kenya published guidelines on blockchain-based cryptocurrencies; and the Office of the Data Protection Commissioner whose mission is to protect personal data through compliance, enforcement, public awareness and institutional capacity development. Additional government plans guiding the sector include the Digital Economy Blueprint (2019) and the Kenya National Digital Masterplan (2022).

Further, to ensure a responsive, robust and innovative regulatory environment, the Ministry of Information, Communications and Digital Economy in 2023 is updating the Kenya Information and Communication Act regulations. The revisions shall account for the changes in the sector, address current challenges and exploit emerging opportunities. Regulations under revision include the following:[68]

- Compliance and Enforcement Regulations, 2023
- Consumer Protection Regulations, 2023
- Domain Name Administration Regulations, 2023
- Electronic Certification Administration Regulations, 2023
- Fair Competition Regulations, 2023
- General Licensing Regulations, 2023
- Numbering Regulations, 2023
- Postal and Courier Services Regulations, 2023
- Radio Communications and Frequency Spectrum Regulations, 2023
- Tariff Regulations, 2023
- Type Approval, Importation and Distribution of Communication Equipment Regulations, 2023
- Universal Access and Service Regulations, 2023

One of the applications of blockchain technologies is cryptocurrencies. In Kenya, the uncertainties associated with cryptocurrencies have generated significant debate on developing and implementing robust and up-to-date regulatory provisions to mitigate the risks.[69]. Some argue that adopting cryptocurrencies threatens the centralisation of banking services that allow regulators to play the watchdog role. The currencies could also provide avenues for money laundering and financing of terrorism activities.[70] Kenya does not have express regulatory provisions for cryptocurrencies. The Central Bank of Kenya has only issued cautionary statements to the public[71]. In Civil Suit No. 08 of 2019 at the Milimani Commercial and Tax Division, the judge ruled that cryptocurrencies can be identified as securities, placing them within the regulatory scope of the Capital Markets Authority[72].

Several regulations have also been implemented, especially governing the financial services sector that has widely adopted EDT. These include the *Digital Credit Providers Regulations 2021* by the Central Bank of Kenya that provide for, among other things, licensing of digital credit businesses and requirements for digital credit providers to put policies, procedures and systems in place to ensure the confidentiality of customers' information and transactions. These include circumstances for sharing customer information with licensed credit reference bureaus (CRB), limitations on using customer information obtained from CRB, to whom CRB can release

[64] Haskew et al. (2015a), Haskew et al. (2015b)
[65] https://www.numeraliot.com
[66] https://hellotractor.com
[67] Kenya ICT Action Network, kictaet.net
[68] https://ict.go.ke
[69] Arunda, B., (2021)
[70] *Ibid*
[71] *Ibid*
[72] *Ibid*

information, and various consumer protection requirements. These include receipts for all transactions, establishing customer complaints resolution, systems integrity, divulging detailed and accurate product information, avoiding false advertisements and variation of credit terms.

A review of tax laws has also sought to keep up with the digital economy. For example, the Finance Act of 2019 and 2020 were amended to address gaps concerning digital economy taxation. Within the laws, digital service includes the supply of downloadable digital content, subscription-based media, software programs, products on online marketplaces, digital media content, data management services, search engine services, and any other supply determined by the Commissioner of Domestic Taxes. Most of these services are built on EDT. In the *Income Tax (Digital Service Tax) Act 2020*, all businesses selling services online must pay a flat tax of 1.5% on the value of services offered through digital platforms and a 16% Value Added Tax (VAT).

Implementation of these tax regimes in the digital space continues to present several challenges, including[73]

(a) The restrictive nature of the physical presence provisions, especially on the definition of permanent establishment and the various double tax treaties in determining income taxable in Kenya.

(b) Difficulties in collecting taxes from non-residents without a presence in Kenya, especially for VAT cases.

(c) Complexities that arise from seeking to define consumption places for calculating VAT and other indirect taxes.

(d) Difficulties in generating a taxpayers list to enhance the identification of services provided, their status as resident or non-resident, the value of services provided and compliance levels with the relevant tax laws.

(e) Inadequate access to digital transaction data, making it challenging to identify and track online transactions.

(f) Lack of consensus on taxation of the digital economy at global levels.

Most researchers and innovators surveyed agreed or strongly agreed (40%) that the current government policies supported research and development of applications in EDT/X-Data. However, 32% disagreed or strongly disagreed, and 28% had a neutral opinion. Of the surveyed policymakers, 50% agreed that the policies were supportive, with 20% strongly disagreeing and 30% neutral. These similar sentiments show that there is room for improvement of the existing policies supporting the research on and application of EDT/X-Data. The surveyed policymakers also indicated that research outputs adequately inform decisions and policies that directly or indirectly affect EDT/X-Data (70% strongly agreed or agreed).

The surveyed stakeholders recommended six policy areas to strengthen or develop policies:

(a) Capacity building: Policies to promote the training of individuals in data science and analytics, machine learning, and other related fields could help to build a skilled workforce capable of developing and analysing EDT/X-Data.

(b) Data collection and sharing: Clear policies to regulate the collection, sharing, and use of data, including real-time data, open data, and user-generated data, that ensure ethical and legal data collection that is shared in a way to maximise its benefits to stakeholders, while protecting privacy and confidentiality.

(c) Incentives and funding: Policies to incentivise the adoption and use of EDT and X-Data, including the provision of funding or tax incentives for stakeholders who invest in these technologies, as well as the establishment of prizes or awards for innovation and best practices in the use of EDT and X-Data.

(d) Public-private partnerships: Policies to promote public-private partnerships that support the development and application of EDT and X-Data, including the development of joint initiatives between government agencies, private sector companies, and civil society organisations, as well as the establishment of

Case Study 1: Capital Markets Authority Regulatory Sandbox

The Capital Markets Authority (CMA) Regulatory Sandbox is a tailored regulatory environment that allows for the live testing of innovative capital markets-related products, solutions and services with the potential to deepen and develop the capital markets before launching into the mass market.

The live testing is conducted under a less onerous regulatory regime. It is expected to attract fintech companies and existing capital markets intermediaries seeking to add value by applying technology to financial services, among other innovations.

The platform shall help CMA understand the emerging trends in financial technologies. It provides an evidence-based tool for fostering innovation and regulation while at the same time allowing the Authority to remain vigilant to investor protection, financial stability and integrity risks.

Regulatory Sandbox Policy Guidance Note 2019 governs the sandbox platform and provides the framework for its establishment. The framework further provides the eligibility, application, safeguard, and testing requirements for firms interested in live testing their innovative products, solutions or services within the sandbox.

Source: CMA Sandbox, https://sandbox.cma.or.ke/index.php/what-it-is

[73] Kenya Revenue Authority, (2020)

Table 2.6: Maturity of the different stages in the EDT/X-Data Ecosystem in Kenya

Fundamental Activities	Stage	Remarks
Education	Growth	• 52.4% of all universities offer an undergraduate programme providing a solid foundation for those who may go into the workforce related to emerging digital technologies or pursue further studies; • Only 12.7% and 6.3% of universities offered related Masters or PhD programmes, respectively, a fraction of the number of undergraduate programmes. • Short courses are available in the core areas of EDT and x-Data
Research	Nascent	• As a fraction of total patents applied for and granted in 2021, EDT (excluding GIS) accounted for only 10.75 and 8.3%, respectively; • Journal publications based on local research in EDT were relatively few, mainly as a result of the small number of researchers working in these areas; • Low commercialisation rates of local research output. However, efforts driven by the Kenya Innovation Agency are supporting universities to commercialise research output.
End-use	Growth	• There is a substantial market demand for and understanding of the potential uses of emerging digital technologies, primarily because they have enabled Kenya to leapfrog legacy systems and offer services leveraging on the country's extensive mobile penetration. • Mobile-based use has strong potential as most people are familiar with using the devices (135% mobile subscriptions, 72% mobile money penetration, 40% internet penetration).
Linkages	Growth	• Incubators, accelerators, hubs, and associations provide a growing number of formal linkages. • Strong linkages in relevant conferences, workshops and seminars, for example, the Connected Summit organised by the ICT Authority and Ministry in charge of ICT.
Implementation	Growth	• A significant number of startups and established businesses offering new services and products based on the EDT/X-Data, especially in the agricultural, education, financial, health, manufacturing and transport sectors; • Facilitative governance and regulatory framework, which has room for improvement in critical areas of capacity building, data collection and sharing, incentives and funding, public-private partnerships, intellectual property, and sensitisation; • Extensive infrastructure to support the deployment of EDT, including mobile and fibre networks, data centres, and under-sea cable connections. supporting

regulatory frameworks and standards to guide these partnerships.

(e) Intellectual property: Simplifying the patenting process.

(f) Sensitisation: Of all stakeholders on the importance of EDT and X-Data.

Funding Resources

One major challenge that hinders research activities, especially on the EDT/X-Data in Kenya, is limited Research and Development (R&D) resources. Few researchers and institutions can fully sponsor their research activities, thus the need for collaborative research projects to pool resources and seek external research funding. Among the study participants, 60% had funding for their current research activities, with 55% from development partners and 27% from the government. Figure 2.5 shows the funding sources for the study group's research activities. When asked about the availability of funding sources, 67% reported that they were few, and 29% could not identify any.

Strategic government-to-government partnerships enhance science diplomacy and cooperation, provide a platform for bilateral collaborations in innovation-based R&D and promote access to a global strategic networking system and a bigger pool of funding resources. Examples of funders to Kenya include the UK Foreign, Commonwealth and Development Office R&D funding (e.g. UK-Kenya Tech Hub) and GIZ-funded Innovation hubs.

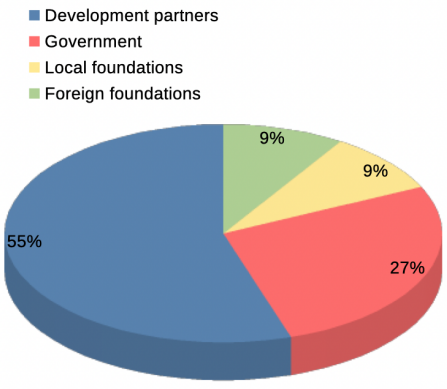


Figure 2.5: Sources of Research Funding for Surveyed EDT/X-Data Researchers and Innovators in Kenya

2.4 Maturity Level

According to the study, the EDT/x-data ecosystem in Kenya is at the **growth stage of maturity**. With reference to Table 2.6, all the fundamental activities had a growth stage rating, except research, which was assessed to be in the nascent stage.

2.5 Summary

Based on the maturity model, the Kenya EDT/X-Data ecosystem is in the growth stage of maturity. The research dimension, however, was assessed to be in the nascent stage, with the key indicators getting stronger. Critical areas for improvement in this dimension include low rates of intellectual property protection, a relatively small number of researchers in the area, low research output (as measured through journal publications), and negligible commercialisation of research output. These weaknesses must be addressed for the ecosystem to significantly address Kenya's socio-economic challenges. All the other dimensions, namely, education, end-use, linkages, and implementation, are in the early stages of growth, placing the country on a promising trajectory to harness the benefits of emerging digital technologies and x-data applications to uplift the well-being of her people and ensure that the country is not left behind in the new digital space.

3. MATURITY OF THE EMERGING DIGITAL TECHNOLOGY ECOSYSTEM IN SOUTH AFRICA

3.1 Primary Actors

The study identified primary actor stakeholders across the maturity model dimensions, including research, education, end-use, and implementation. Actors were drawn from universities, private education institutions, research institutions, and private companies across various sectors. A survey of twelve primary actors (seven male, five female), including researchers and innovators, was conducted to obtain their perspectives on EDT and augment the data obtained from secondary sources. The actors included CEOs, professors, senior lecturers, project managers, and postgraduate students.

Most respondents, 41.7%, had PhD degrees, 25% were ongoing PhD students, and 33.3% were Masters degree graduates. Further, they possessed varied experience levels in academia and research, ranging from below 5 years of experience (41.7%) to between 6 and 15 years of experience (33.3%) and over 15 years (25%). The following our findings.

Education

According to a World Bank report, over 10 South African universities offer programmes and modules on the Fourth Industrial Revolution (4IR) and related fields of AI and robotics, either as short learning programmes or undergraduate and postgraduate programmes and modules. For example, the University of Johannesburg (UJ) offers undergraduate and postgraduate programmes specialising in AI. The university also established a free Massive Open Online Course (MOOCS) on the Introduction to Artificial Intelligence in the 4IR. The course seeks to understand what AI is, its purpose, associated possibilities, and implications, ethically and productively. The course provides the public with access to education on AI, improving their awareness and knowledge of the basics of AI. UJ also offers other courses for continuing professional development (CPD) for Professionals in Business in 4IR, AI and Blockchain Technology in accounting, financial risk, taxation, and risk management and control, among others.

Moreover, various South African Sector Education and Training Authorities (SETA) have developed programmes concerning 4IR technologies. Examples include the BankSETA and the Media, Information and Communication Technologies SETA (MICTSETA), which have set up various digital courses that meet their sectors' demands. Beyond the offerings of programmes in EDT, many learning institutions are incorporating EDT in some of their existing programmes and modules in line with skills demands. For instance, the University of Pretoria integrates notions of Industry 4.0 in all the modules, especially in business and computer engineering programmes, with departments such as the Computer Science Department incorporating a big data science subject area into its Master's course.[74]

Private sector actors also provide education and training on EDT and related areas. For example, the Code4CapeTown programme invests in women/girls coders and programmers, promoting their involvement and representation in the field. According to their website, participants are trained in web development, design principles, coding using different languages (Python, javascript), and social innovation. Also, Blockchain Academy provides training and consulting on blockchain technology for beginners, executives, and developers on blockchain technology.[75]

The African Institute for Mathematical Sciences (AIMS) South Africa offers the AI for Science programme under the Master's degree in Mathematical Science and seeks to attract students from across Africa. The one-year programme is appropriate for those interested in Mathematics, AI and Machine Learning (ML).[76]

Despite the view that the South African education system is advancing to include EDT in the curricula, more must be done to link qualification offerings with new and changing job demands, necessitating additional technology-specific training during employment. Further, the number of STEM graduates produced for academia does not meet demand, and there needs to be more systems to train and retrain workers in emerging technologies and ICT.[77]

However, an increasing number of technology hubs and sources of finance are available in the country for startups. The lack of skills and professional expertise can be attributed to the high cost of educating and retraining the workforce.[78] There is also a lack of knowledge on blockchain. For example, organisation executives associate it only with cryptocurrency without understanding it can significantly improve the industry. South Africa also needs more computing and engineering capacity to train large language models for machine learning-based AI systems.[79] These gaps can also be attributed to poor primary and secondary school education and the limited curricula in technical and vocational colleges.[80] Of the surveyed study participants, 33% had taken various courses and training on EDT/X-Data (see Table 3.1).

Research

EDT/X-Data applications have emerged as phenomenal drivers of solutions to various corporate and socio-economic challenges in both developing and developed countries. The applications cut across several sectors, including agriculture, health, governance, safety and security. Table 3.2 shows the various sectors targeted by the survey respondents.

[74] Mzekandaba (2019)
[75] Dogo et al. (2019)
[76] AIMS (n.d.)
[77] Sutherland (2020)
[78] Akinradewo et al (2022)
[79] Barrett (2023)
[80] Jenkin and Naude (2018)

Table 3.1: EDT/X-Data-Related Courses Attended by Surveyed EDT/X-Data Researchers and Innovators in South Africa

Course	Percent
Artificial Intelligence	29%
EDT Applications	29%
Big data	14%
Data Science	14%
Machine learning	14%

Table 3.2: Sectors Targeted by Surveyed EDT/X-Data Researchers and Innovators in South Africa

Sector	Number	Percent
Health	3	23%
Industry and Manufacturing (Smart)	3	23%
Energy (including renewable energy)	2	15%
Business/Entrepreneurship	1	8%
Financial Services (FinTech)	1	8%
Education	1	8%
Agriculture	1	8%

Council for Scientific and Industrial Research (CSIR) is one of the leading research institutes in the country and is actively involved in research, development and innovation (RD&I). CSIR aims to enhance socio-economic prosperity in South Africa through the research, development, localisation, and diffusion of technologies, thus contributing to industrial development. CSIR has a research centre for Emerging Digital Technologies for the Fourth Industrial Revolution (EDT4IR), which seeks to strengthen the RD&I community of practice in the EDT. The centre produces research knowledge and contributes to developing capabilities from human capital, technology tools and infrastructure associated with AI, advanced Internet of Things (IoT), and distributed ledger technology, among other things. The research centre also focuses on building demonstration tools for the practical application of transformative technology and offering digital tools that will promote the implementation of smart solutions. The centre has three research groups aligned to its focus areas: Artificial Intelligence and Extended Reality, Distributed Ledger Technologies, and Advanced IoT.[81]

The Centre for Artificial Intelligence Research (CAIR) is an example of a collaborative institution between universities and other stakeholders. It was established in 2011 and is coordinated by CSIR and funded by the Department of Science and Innovation (DSI). CAIR links nine research groups from six universities—the University of Cape Town, the University of KwaZulu-Natal, North-West University, the University of Pretoria, Stellenbosch University and the University of the Western Cape. The research focuses on various aspects of AI, including adaptive and Cognitive Systems, AI and Cybersecurity, AI for Development, Applications of Machine Learning, Computational Logic, Ethics of AI, Foundations of Machine Learning, Knowledge Representation and Reasoning, and Probabilistic Modelling. CAIR seeks to develop world-class research capability in the identified areas of AI through consolidated, applied AI research initiatives, building an accredited national and international AI research network that promotes AI research and technology in the country.[82]

The Artificial Intelligence Institute of South Africa (AIISA) was founded by the University of Johannesburg, TUT(??), the Department of Communications and Digital Technologies. The institute is based on the vision of the Presidential Commission on the Fourth Industrial Revolution. (PC4IR). AIISA focuses on three sectors of the economy: the fourth industrial revolution in manufacturing, healthcare, agriculture, and food processing, to produce knowledge and applications that will enhance South Africa's competitiveness in the global AI sphere.[83]

Several research chairs and centres have been established across the country. For example, the University of Pretoria's Faculty of Engineering, Built Environment and IT (EBIT) was awarded the Chair in Machine Learning for Sustainable Development, which focuses on the use of AI approaches to enhance the quality of life and promote sustainable development while aiming to produce leading researchers in the AI field.[84]

Also, the DSI/NRF-Sasol Research Chair in Energy and Power Systems Modelling (UCT) focuses on various aspects of energy transition. It contributes to developing energy solutions and advancing knowledge and skills for sustainable development in the country. The Research Chair promotes using data-driven approaches, such as AI, artificial neural networks (ANN), and machine learning, in energy planning and finding optimal solutions. It seeks to strengthen and improve public universities' research and innovation capacity to generate high-quality and excellent research and innovation outputs and researchers. The Chair has the advantage of exposure to industry players, specifically Sasol, promoting research outputs based on academia-industry partnerships.

The University of Johannesburg also runs a research chair on 4IR in partnership with the Education, Training and Development Practices (ETDP) SETA. Other research activities fall within 4IR Centres of Excellence in TVET Colleges, with 10 TVET colleges receiving financial support to set up 4IR mini laboratories. The colleges shall collaborate with the relevant industries to execute the programmes. Other publicly funded research chairs are held in various South African universities focusing on AI, AI systems, blockchain technologies and machine learning for sustainable development. This diversity mirrors the responses from the surveyed participants, of whom most (91.7%) had ongoing research based on some or all the EDT (see Figure 3.1).

The country has also experienced significant growth in ICT research activities, evidenced by the growing number of research hubs focusing on different aspects of EDT, including mobile robotics, computational intelligence, knowledge representation and reasoning, and human language technologies.[85] These groups include the Computational Intelligence Research Group (CIRG), Robotics and Agents Lab

[81]CSIR (n.d.)

[82]https://www.cair.org.za/about
[83]AIISA, (n.d), Stoltz (2023)
[84]UP News (2022)
[85]Ferrein and Meyer (2012)

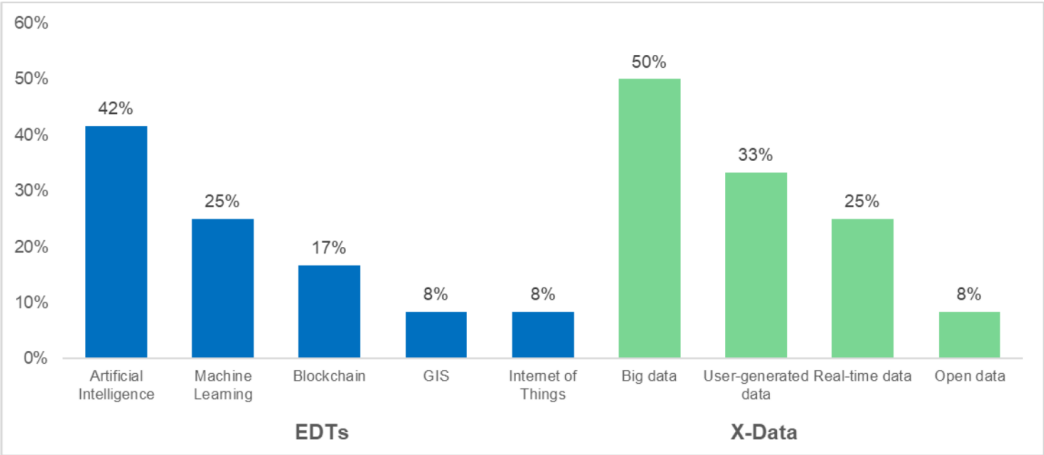


Figure 3.1: Percent of Surveyed Researchers and Innovators in Kenya using different types of EDT/ X-Data

(RAL), Human Language Technologies Group, and Mobile Intelligent Autonomous Systems Group (MIAS).

There are also research activities in the Transport sector where AI-based algorithms use real-time traffic data to alleviate traffic congestion, accidents and high pollution rates caused by increased urban traffic flow. For example, data collected from the Mikos Traffic Monitoring (essentially sensors embedded on road surfaces to monitor and control vehicles) was used with AI techniques to reduce and control traffic by predicting the traffic flow ten minutes into the future.[86]

Journal publications play a critical role in disseminating research findings and knowledge transfer. A Scopus search of publications containing "Artificial intelligence" AND "South Africa" in either their title, abstract or keywords returned 332 publications. Similar searches for other BRICS countries returned publications for Brazil at 780, Russia at 687, India at 2,434, and China at 6,882, ranking South Africa at the bottom. When compared to other African countries, Kenya (79), Nigeria (182) and Egypt (191), South Africa leads on the continent. South Africa's annual publications have risen steadily from 5 in 2009 to 63 in 2022. Of the 332 publications, 43% were journal publications, and 40% were conference papers. By discipline, 23% were in computing science, 14% were in engineering, and 10% in social sciences. South African-based researchers were first authors on most publications, and the main funders (where acknowledged) were the South African National Research Foundation, followed by the University of Johannesburg.

The relatively low number of publications found in Scopus mirrors the findings from our survey. Table 3.3 shows the distribution of participant publications related to EDT/X-Data. A small proportion of the surveyed researchers (16.7%) in South Africa's EDT/X-Data ecosystem had published in journals. The majority, 83.3%, however, had not. Their ongoing research activities are at different stages, as presented in Figure 3.2.

Patents and other intellectual property protection measures provide pathways to commercialising research output.[87] Protecting intellectual properties derived from research and innovation on EDT/X-Data is essential to safeguard the benefits yielded upon deployment and commercialisation. However, only 8% of the surveyed study participants had patented or copyrighted their research/innovation outputs related to EDT/X-Data. These findings signal concern, especially noting that 63% indicated that their research outputs were ready for publication, deployment, or commercialisation. Critical interventions are required to sensitise and facilitate the researchers and innovators to protect their work and build up on the 17% who indicated that they are likely to file for a patent or copyright in the next year.

Table 3.3: Number of publications Directly Related to EDT/X-Data by Surveyed Researchers and Innovators in South Africa

No. Publications	No. Researchers	Percent
0	10	83.3%
2	1	8.3%
10	1	8.3%

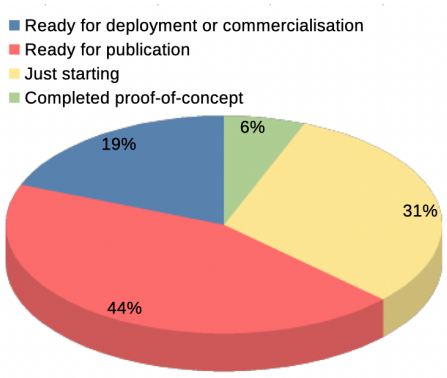


Figure 3.2: Stage of Current EDT/X-Data Research Activities of Surveyed EDT/X-Data Researchers and Innovators in South Africa

Whereas funding, knowledge and skills are necessary to carry out impactful research and develop solution-based applications in the EDT/X-Data ecosystem, having the necessary infrastructure, equipment, and a conducive policy environment is equally important. Only 34% of the surveyed participants, however, agreed that they have the necessary equipment and tools to carry out research work in the area of EDT/X-Data, whereas 42% were neutral and 25% disagreed. Therefore, more

[86] Olayode et al. (2020)
[87] Jooste (2023)

Table 3.4: Challenges Faced by Surveyed Researchers and Innovators in South Africa in the EDT/X-Data Ecosystem

Area (Frequency)	Description	When Used	Sample Quotes
Emergent Theme 1: Data			
Access to/availability of Big data (5)	Ability to access Big Data from other organisations	All references to the inability to access or the unavailability of required data.	"To get the data is a challenge." "Access to interviewees/ case studies."
Quality of data (2)			
Emergent Theme 2: Rapid advancement in EDT			
Rapid advancement in the technologies (5)	Rapid developments in EDT	All references to challenges emanating from rapid developments in EDT	"Awareness challenges since the area is still emerging." "Slow technology adoption." "Participant technological proficiency."
Emergent Theme 3: Inadequate Resources			
Research funds (3)	Funding for research in EDT and X-Data	All references to inadequate funding or few sources of funding.	"Scarce funding."
Limited non-financial resources (2)	Non-financial resources available for EDT and X-Data research	All reference to inadequate non-financial resources.	"Lack of appropriate non-funding support

must be done to provide researchers with the necessary infrastructure.

Survey participants were also asked to state the top three challenges they faced. The QCA analysis revealed three emergent themes: data, rapid advancement in EDT, and inadequate resources. A description of each theme is presented in Table 3.4, together with sample quotations from the respondents, thereby placing the derived theme in a better context. Single proposals were omitted. The themes suggest possible intervention areas to strengthen the EDT/X-Data ecosystem in South Africa. Issues surrounding data were the primary identified challenges, specifically access, availability and data quality.

End Users

The use of interactive digital technology and access to the Internet is essential to enable organisations to have a digital presence in the era of 4IR. In South Africa, various sectors are involved in end-use activity, including construction, built-environment, mining, health, agriculture, energy and insurance. Organisations, businesses and individuals all use various technologies, which include AI, Blockchain, IoT and Big Data Analytics, to stay competitive. These technologies are adopted in multiple functions of organisations, including supply chain, operations and marketing, to improve services and remain competitive and relevant. The technologies enable access to real-time information and enhanced communication for end-users.

Nonetheless, the rate of adoption of these technologies remains slow. South Africa has a higher internet penetration rate than other African countries. As of 2023, the country had approximately 43.48 million active internet users, accounting for 72.3% of its population, while active social media users accounted for just under 43% of the population.[88] Also, approximately 78% of the population used mobile phones to access the Internet in 2022, and smartphone users accounted for a third of the country's population.[89] These figures shall increase in the next few years as the South African government targets to meet universal web access for all its citizens' households by 2024. Other factors affect access to the Internet and the adoption of digital technologies in South Africa. Among these are inadequacies in infrastructure and equipment; for example, many end-users do not have the required devices to accommodate the levels of data or information received and produced. Also, improved infrastructure is needed in parts of South Africa to boost Wi-Fi coverage and affordability.[90]

Digital illiteracy and security concerns are some of the main hindrances to accessing and fully utilising various platforms and data. For example, there are concerns about the illegal use of collected data for other activities. Within the business community, there are difficulties and complexities in changing organisational culture to digital options and the fear of disruption to existing jobs.[91]

As such, there is a need to bridge this digital divide. Organisations such as the Silulo and tech incubators like Bandwidth Barn have made efforts towards making the Internet and the digital space accessible for entrepreneurs. However, these initiatives require support to remain sustainable and to reach a wider audience. There is also a need to upskill

[88] Cowling (2023)
[89] Taylor (2023)
[90] Mlaba (2021)
[91] Vimal, et al. (2023)

individuals and organisations, particularly SMMEs, on digital technologies.

Linkages

Over the past years, South Africa has witnessed a rise in partnerships to advance 4IR interventions. Government departments, government agencies, and universities interact through joint initiatives, for example, CAIR and AIISA. There are also interactions between academia and industry, such as CSIR's interaction with universities through various programmes and research centres. These interactions are essential for meeting skills requirements and work placements, which also promotes matching skills requirements and knowledge.[92]

Other interactions occur across government, industry and academia stakeholders. One such example is the DSI, NRF & Sasol partnership, which recently awarded grants to four South African Research Chairs (SARChI) and six Postdoctoral Innovation Programme Fellowships to stimulate and accelerate joint industry-academia research in clean and sustainable energy and contribute to South Africa's transition towards sustainable clean energy and a Just Energy Transition (JET). SARChIs are examples of interactions between government (DSI), academic institutions and funders (NRF) aimed at expanding research and innovation (R&I) capacity while responding to social and economic challenges and attracting and retaining excellent researchers to advance knowledge.

Other examples of interactions include the DHET Partnership with CISCO and HUAWEI to ensure alignment of existing TVET colleges curricula with industry demands in the digital skills area. Through the CISCO agreement, 3 thousand lecturers are being trained and upskilled in 50 TVET Colleges on ICT-related qualifications. The Huawei partnership focuses on training lecturers from TVET colleges to support the introduction of subjects, including Routing and Switching, Big Data, Artificial Intelligence, and Security and Cloud Computing.[93]

In collaboration with DFFE (DEA then), the Open Data South Africa project hosted training and hackathon events related to the South African Air Quality Information System to investigate new uses of air quality data and improved techniques for monitoring air quality issues. This example illustrates interactions between government agencies and the private sector through joint initiatives enabling the adoption of Big Data in local communities. These training and hackathon events involved teaching local communities how to use and monitor air quality data and tools to understand their living environment. They focused on equipping participants with skills for visualising data and providing networking opportunities between associated civil society groups and technology students. Participants included technology students, young developers and entrepreneurs.

Interactions for knowledge sharing are also taking place within academia. These include research communities in Africa in which South Africa participates, for example, the Deep Learning Indaba, Data Science Africa and the Regional Academic Network on IT Policy.[94] Locally, the South African Artificial Intelligence Association (SAAIA) provides a platform for professionals and enthusiasts, including industry, government, academics, and startups, to promote knowledge sharing, responsible AI commercialisation, and collaboration opportunities.[95]

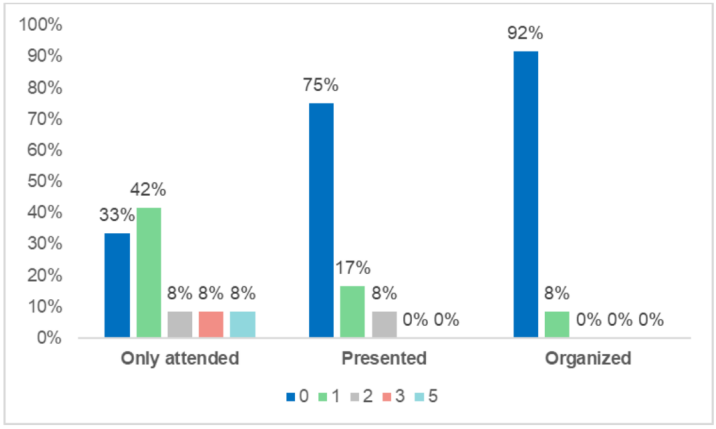


Figure 3.3: Attendance, presentation and organisation of conferences on EDT/X-Data in South Africa by Surveyed Researchers and Innovators

Conferences provide avenues for learning, networking and dissemination of research output. A significant number of the surveyed researchers and innovators, however, had yet to attend (33%), make a presentation (75%) or take part in organising any conference (92%) on EDT/X-Data in South Africa. Overall, 42% had attended only one conference without making any presentations, and 17% had participated in and presented at one conference (see Figure 3.3). Only 8% of the surveyed participants had taken part in organising a conference. When asked about research collaborations, 67% of the surveyed participants had ongoing research partnerships with industry and 42% with universities and research institutions on EDT/X-Data.

Implementation

Implementation of EDT has occurred across various sectors in the country, including agriculture, smart metering, finance, insurance, healthcare, and air quality information systems. A brief presentation on representative examples follows.

Agriculture

The use of EDT in the South African agricultural sector is growing to improve productivity and sustainability. There is active development of applications for crop monitoring and management through satellite imagery and drone data; soil analysis and management using AI algorithms; pest and disease detection through AI-powered systems; smart irrigation; and livestock management. For example, in the Data-Intensive Farm Management (DIFM) project run in various parts of the world, including South Africa, agricultural firms use precision technology to generate and provide data-based, site-specific farm management guidance. Other organisations use drones to provide imagery, AI, machine learning and big data for crop health analysis.[96]

The AI Platform (Hi Saai) was launched in 2023 by the Southern African Agri Initiative (Saai). Hi Saai is a free management support tool that uses billions of Internet data points to establish a framework that offers answers to farm-related questions within minutes. Its services include business and financial-related

[92]Maisiri et al. (2019)
[93]Ministry of Higher Education, Science and Innovation website
[94]Gwagwa et al. (2020)
[95]SAAIA (n.d.)
[96] Ameer-Mia et al. (2020)

issues, chemical applications advice, production planning, and marketing advice. Although it is in its early stages (post-pilot), Hi Saai is expected to be an inclusive platform catering even to the smallest and poorest farmers, provided they have Internet access.

Air Quality Information System

The South African Air Quality Information System (SAAQIS) platform launched by the Department of Environmental Affairs -- now known as the Department of Forestry, Fisheries and Environment (DFFE) -- obtains and visualises data from nationwide monitoring stations.[97] SAAQIS provides air quality information to citizens and serves as a research portal for enhancing policy development on air quality issues.

Finance

Ukheshe Technologies is a fintech organisation that offers solutions for a single API that allows a wide range of payments. The company partners with banks, telcos, and financial services providers to increase financial inclusion through their API framework (Eclipse API), which can be customised to address specific needs to ensure that clients pay and get paid. Some industries utilising this service include banking, telcos, insurance companies, fintechs, government, e-commerce and businesses looking to replace cash handling.[98]

Healthcare

A data-driven healthcare system may contribute to an improved standard of healthcare in South African rural areas (Babbar and Rani, 2022). For example, IoT and cloud computing technologies have created remote patient monitoring in their homes using networks of IoT medical devices equipped with sensors and actuators to collect and process patient healthcare data. The approach could reduce clinical costs and improve the quality of life of patients and their families. Several AI in Healthcare startups have also been established in South Africa over the last decade to improve healthcare provision.

For example, My Doctor is a platform that offers teleconsultation and appointment booking options with healthcare providers. The AI-based platform, developed in 2020, allows users to locate certified healthcare providers, nurses, and home healthcare services based on clients' needs. Innohealth Technologies was established in 2021 and uses clinical expertise, data science, AI and machine learning to provide affordable, value-driven, and customised innovative solutions to African healthcare problems. The platform offers imaging and lab diagnostics solutions for doctors and patients. The company uses its data models and real-time data to determine and analyse trends, patterns, and opportunities for improvement to ensure more improved healthcare delivery. Innohealth has collected approximately 400 thousand health records and conducted over 60 thousand consultations.[99] Accrad (Accelerated Radiology) was established in 2020 to provide AI-based software for X-ray image analysis, which helps radiologists accurately diagnose patients. Accrad established CheXRad, a deep-learning algorithm that identifies diseases on X-ray images at a level comparable to practising radiologists.[100]

Insurance

Implementation of EDT in insurance companies is considered a response to the cumbersome processes and poor customer service provided by other traditional approaches. For example, Naked Insurance is an AI-driven company that has eliminated human interaction in its buying process. Established in 2018, the company offers motor and home cover. It enables their clients to buy cover through the application where AI bots provide estimates, using the provided individual's profile and relevant demographics, credit records, and required cover. The platform stores data from every quote to improve the system's accuracy by identifying how far off estimates are from the actual value when claims are processed.[101] Granadilla Insurance also uses an AI chatbot named 'Nandi' for client interactions, avoiding human interaction and physical "brick and mortar" infrastructure. Nandi offers a quick and seamless onboarding user experience with cover provided within 24 hours.[102]

Manufacturing

In the automotive and manufacturing industries, EDT have been demonstrated to improve organisational performance, lower costs, enhance quality and accelerate responsiveness.[103] The autonomous decision-making powers of these technologies result in a high level of flexibility on the shop floor. Smart manufacturing technology will likely improve productivity by 12%, and overall equipment efficiency can improve by as much as 35%. Sappi, a company that provides everyday materials made from wood fibre-based renewable resources, has witnessed the impact of smart technology in improving international competitiveness. Its Saiccor Mill underwent a $480 million technology revamp, resulting in the construction of one of the world's largest dedicated dissolving pulp plants. The revamp provided automation, electrification and instrumentation upgrades, allowing remote access and mobility. Through this project, the company has achieved impressive sustainability impacts, including a 17% reduction in water usage and a 40% minimum reduction in its carbon footprint. It has increased its production by 110 thousand tons.[104]

Mining

The mining sector uses big data and EDT in its logistics functions, where logistics systems can autonomously relay information to those responsible for the logistics process. It uses IoT, AI, and data to plan machine loadings, vehicle schedules, routes, and deliveries.[105]

Smart Metering

There are numerous businesses in smart metering for water demand management, including Aqua Loc, Amanzi Meters, Lesira-Teq Smart Metering, Krohne, and Ideal Repaid. Smart meters generate, collect and display real-time data, enabling prompt decision-making. Lesira-Teq, for example, is a Pretoria-based company that designs, manufactures and supplies technologically advanced, user-friendly, and reliable smart water meters globally. The 20-year-old company continues to enhance its product and service offerings through advanced innovation and development interventions that allow for intelligent, high-quality water management. IoT-enabled smart meters provide wireless transmission of daily updates on usage or leakages to the end user, improving consumption management.[106]

Tourism

[97] https://saaqis.environment.gov.za/, Open Data South Africa (2022)
[98] https://www.ukheshe.com/
[99] https://www.innohealthts.com/
[100] http://accrad.com/
[101] https://www.naked.insure/blog
[102] https://granadillaworld.co.za/
[103] Bag et al. (2021c)
[104] Sappi (n.d.), CNN (2022)
[105] Bag et al. (2020)
[106] https://lesira.co.za/service/smart-water-meter/

To ensure a sustainable national park system, national parks in South Africa, including Kruger National Park, Addo Elephant National Park, Table Mountain National Park and Garden Route National Park, are using user-generated data from social media to understand visitors' attitudes, perceptions and values of the parks. Questionnaires were previously used and were costly and limited in space and time (capturing only a snapshot). User-generated data provides real-time data in the form of videos, text and pictures on social media, which proves helpful to the parks.[107]

3.2 Secondary Actors

Several government departments and agencies were identified as secondary actors in the EDT/X-Data ecosystem. They include the Department of Trade and Industry and Competition (DTIC), the Department of Public Service and Administration (DPSA), and the Centre for Public Service Innovation (CPSI). These departments and agencies guide firms to operate within social boundaries through the national digital strategy. They also enforce rules and regulations protecting the safe usage of data within the framework of regulatory norms.[108]

There are actors in the private sector that influence the primary actors' use of X-data. For example, the Open Data South Africa (ODSA) partners, in collaboration with DPSA and CPSI, promote the advanced use of government data in local communities for social impact by facilitating community engagements and updating the open data portal for easy navigation and access (Open Data South Africa, 2022). X-data consulting firms also offer services such as data consolidation and warehousing, data analysis and business analytics solutions that influence primary actors' decision-making.

The government could play a more significant role in several areas, including creating awareness, developing relevant policies (data protection policies, cybersecurity policies), and upgrading digital infrastructure to ensure connectivity that can carry and sustain digital technology applications. Policymakers in South Africa should also play a more prominent role in the ecosystem. Areas for strengthening include the setting up of digital platforms for the public to submit information for analysis and examination of trends (for example, in the health sector), developing clear digital policies to avoid traceability and misuse of the information, policymakers, and creating awareness of policies among the public to encourage the submission of information by the public.[109]

Governance Frameworks

Government regulation dominates South Africa's EDT ecosystem through policies and laws relating to intellectual property, data protection, and research and development incentives. There is also legislation that indirectly impacts EDT and X-data innovation, for example, support for local technology production or health and safety legislation. Examples of these are outlined below. First, regulations that directly impact EDT and X-Data innovation include:

(a) *Income Tax Act of 1962:* Section 11D allows for a deduction equal to 150% of expenditure incurred directly for research and development and an accelerated depreciation deduction (50:30:20) for capital expenditure incurred on machinery or plant used for R&D.

(b) *Protection of Personal Information (POPI) Act - No.4 of 2013*: Section 71(1) of POPIA, which governs automated decision-making, is crucial for AI systems, given their inherent problem-solving ability. This section protects data subjects from being subjected to a decision based solely on automated decision-making, which results in legal consequences for the data subject and the profiled data subject.

(c) *Protection of Personal Information (POPI) Act:* All of this Act but especially No.4 of 2013, section 57(1)(a) that requires a responsible party to obtain prior authorisation from the Information Regulator if it intends to process any unique identifiers of data subjects (i) for another purpose than intended at collection and (ii) to link the information with information processed by other responsible parties.

(d) *Copyright Act, No.98 of 1978:* Provides for the protection of computer programs and includes computer-assisted and computer-generated works. The author of a computer-generated work will be regarded as the person who created the AI system or the algorithm used to create the work.

(e) *Patent Act 57 of 1978 and amendments:* South Africa has related copyright, designs and trademark acts. In 2018, the government began a phased approach to revising the country's IP policies to ensure they are up-to-date and meet global standards. The first phase of this revision focused on the regulations in the medical and health sectors and how they align with international standards. They provide a framework for patenting new inventions in trade, industry or agriculture.

(f) *Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008:* Determines the ownership of inventions developed with public funding and the distribution of profits from the commercialisation.

Those that indirectly impact EDT and X-Data innovation include:

(a) *Commercialisation Framework (2015/2016):* In collaboration with the Development Bank of South Africa and the Industrial Development Corporation, the DSI supports locally developed technologies with commercial potential.

(b) *The Occupational Health and Safety Act 85 of 1993:* Provides for the health and safety of persons at work and those in connection with the use of plant and machinery. Such legislation can incentivise firms to develop new AI-driven safety technologies or create additional compliance requirements hindering innovation.

(c) *Consumer Protection Act 68 of 2008:* Aims, among others, to promote fair business practices and protect consumers from unconscionable, unfair, unreasonable, unjust, or improper trade practices and deceptive, misleading, unfair, or fraudulent conduct.

(d) *Skills Development Act, 1998 and amendment of 2003 and Skills Development Levies Act, 1999:* Dedicated regulations that set up training and skills development institutions known as SITAs and

[107]Hausmann et al. (2020)
[108]Bag et al. (2021c)
[109]Bag et al. (2021) and Sutherland (2020)

imposed a 1% skills development levy on all employers to assist in funding the same.

(e) *National Digital and Future Skills Strategy, 2020:* It was introduced by the Department of Communications and Digital Technologies to provide a blueprint for upskilling South Africa's population with a range of digital skills, especially AI, big data, IoT and robotics skills.

It is worth noting that South Africa is the first country to award an AI-generated patent in 2021 to DABUS, an AI application invested by Dr. Stephen Thaler. Other countries, such as the United States and the United Kingdom, have not awarded DABUS a patent, citing that the inventor must be human.

South Africa is one of the seventeen (out of fifty-five) African Union States that has enacted comprehensive data protection and privacy legislation.[110] The Protection of Personal Information (POPI) Act addresses the issues of data protection and privacy as it highlights the conditions for accessing, processing and storing personal information affiliated with other parties and individuals. Although X-Data as a concept is not directly regulated in this Act, any exercise involving personal data analysis requires the consideration of the POPI Act.[111] The Act has been criticised for its complexity and it and other existing frameworks not adequately addressing privacy and security concerns surrounding the data generated by IoT equipment, problems with who has access to the data and the potential misuse of the traceability and visibility of this data.[112]

In recent years, South Africa has moved from a top-down government approach to an enabling governance approach, experimenting with several forms of agile governance, including anticipatory governance and outcomes-based regulation. For example, in response to the PC4IR report recommendations, the government set up the Intergovernmental FinTech Working Group (IFWG) that has experimented with an anticipatory visioning of fintech regulation requirements, setting up experimental sandboxes, promoting joined-up regulatory efforts across all finance actors and testing data-driven blockchain technology for interbank transfers. In addition, the government has moved to an outcome-based approach to all public policy development across all levels of government, including twelve outcomes or 'changed states of being' for all government activities. These include improved health, food security, safety, and a protected environment.

From the perspective of the surveyed participants, only 25% agreed that the current government policies support EDT/X-Data research and applications in South Africa. However, 33% disagreed, and 42% were neutral. These views support the analysis from secondary sources that more needs to be done by the government to strengthen existing policy frameworks that impact the EDT/X-Data ecosystem. The survey participants made three recommendations on policies that should be strengthened or put in place to address the following areas:

(a) *AI-specific policies:* Policies that directly support the development of the AI ecosystem.

(b) *Data collection and sharing:* Clear policies to regulate data collection, sharing, and use that also protect privacy and confidentiality.

(c) *Capacity-building:* Policies to support EDT skills development, including courses strengthening better data acquisition practices.

Funding Resources

A major challenge that hinders research activities, especially on EDT/X-Data in the Global South, is the limited resources available for Research and Development. Few researchers and institutions surveyed fully sponsor their research activities, making the case for more collaborative research projects to pool resources and seek external research funding. Of the surveyed participants, 50% had funding for their research activities. Funding came from various sources, including the government, development partners, and local and foreign foundations (see Figure 3.4). When asked about the level of funding, all participants disagreed that there were plenty or even adequate funding sources. Most of them (73%) indicated that funding sources were few. Most of South Africa's R&D funding comes from the government (56.3%), with the private sector contributing 26.9%.[113]

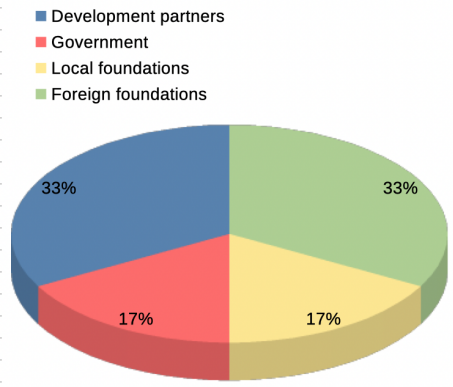


Figure 3.4: Sources of Research Funding for Surveyed EDT/X-Data Researchers and Innovators in South Africa

The largest funders in this space are the National Research Foundation, the Technology Innovation Agency, the Industrial Development Corporation and the Department of Science and Innovation. South Africa also has a vibrant innovation and startup culture supported by several incubation hubs, for example, the Innovation Hub[114] and Tshimologong based at Witwatersrand University. Significant private-sector funding has also been made available for EDT and X-data-related projects in South Africa. For example, Areobotics is a South African startup founded in 2014 that provides tools for precision agriculture. The company has raised US$27 million, with the latest round of US$17 million announced in January 2021. The Internet investment company Naspers, the South African bank, Nedbank and 4Di Capital, a South African-based early-stage venture capital firm, have been the leading funders.

HealthLeap is a South African health tech firm. It was awarded US$1.1 million pre-seed funding in early 2022 by venture capitalist Fifty Years to develop a clinical aid for dieticians focusing on the US market. The Awareness Company (Pty) Ltd was founded in 2018 and uses data-driven storytelling combining AI, IoT and data analytics to create solutions for agriculture and conservation, safety and security, and smart

[110]Gwagwa et al. (2020)
[111]Ameer-Mia, Pienaar, and Kekana (2020)
[112]Dogo et al. (2019), Bag et al. (2021)
[113]DSI (2023)
[114]https://www.theinnovationhub.com

buildings and cities. Microsoft South Africa has funded the development of agricultural applications of its HYDRA technology (risk mitigation software). Microsoft has also funded Vantage Health Technologies, a South Africa-based company that provides cloud-based and AI solutions for health equity challenges.

FinChatBot, established in 2016 to provide automated customer service in the finance sector, has received investment from French investment holding company Saviu Ventures, the Mauritius-based Compass Venture Capital, and South African venture capital firm Kalon Venture Partners. 4Di Capital and Kalon Venture Partners are established South African venture capital firms. Together with Knife Capital, they are the most frequently cited venture capital firms in the disruptive tech space based in South Africa. Other large investment firms financing EDT/X-data-focused firms include Investec and Ethos Capital, which has a dedicated AI venture capital fund. Charitable foundations are also supporting EDT/X-data research and commercialisation projects. For example, Medsol Breast AI, an online patient-based platform that receives images for ultrasound units, received funding in 2021 from the SAB Foundation.

3.3 Maturity Level

The study assessment of the EDT/x-data ecosystem in South Africa determined that the level of maturity is at the growth stage. As detailed in Table 3.5, all the fundamental activities are within the growth stage.

3.4 Summary

South Africa is squarely at the growth stage of the innovation ecosystem maturity model for EDT/X-data technologies. It has a growing education sector, a relatively mature research and implementation environment, and a robust range of involved stakeholders, providing a facilitatory climate. However, the technologies are still emerging and must be fully embedded within the economy and society. This results from a persistent skills and finance gap with some scepticism of the technologies by end-users. Moves towards more facilitatory and agile regulation must continue with a stronger focus on skills training, especially outside the university system.

Table 3.5: Maturity of the Different Stages in the Emerging Digital Technologies/X-Data Ecosystem in South Africa

Fundamental Activities	Stage	Remarks
Education	Growth	• Over ten universities offer postgraduate programmes in AI and data analytics-related subjects. • TVET and SETAs have embraced 4IR technology programmes, and the school-age education curriculum includes coding and robotics. • There are still skills gaps and concerns about the employability of graduates.
Research	Growth	• AI and X-data research are taking place in multiple sectors. • Several collaborative research centres have been set up since 2011, others since the PC4IR report in 2019. • The South African government funds four research chairs on AI and related areas. • South Africa has more patents and publications than other African countries but is the lowest among the BRICS countries. • Challenges researchers and innovators face include funding, access to big data sets, and keeping up with the rapid developments in the sector.
End-use	Growth	• Higher than average African Internet penetration rates at 72% and significantly higher than the global average for daily hours connected to the Internet. • Allied government agencies actively support EDT and X-Data through the National Digital Strategy.
Linkages	Growth	• There are increasing partnerships between researchers and other stakeholders within and outside South Africa. • Several public-private partnerships. • Several industry associations and researcher networks must coalesce research and practice in EDT and data analytics. • A high level of interest in this area of research and innovation has remained since the establishment of PC4IR.
Implementation	Growth	• EDT are used by many organisations, especially by large and small firms in the private sector and government agencies. • Multiple sectors use these technologies, including insurance, customer services, health and agriculture. • Agile and facilitatory governance approaches, including anticipatory regulation and outcome-based processes, are replacing traditional top-down government-dominated regulation models. • Government and private sector funding, including early-stage venture capital support from South African-based and international companies, are available

4. GENDER EQUALITY AND SOCIAL INCLUSION

4.1 Introduction

EDT can transform our abilities to achieve global, national and regional goals. For instance, while AI technologies and applications have the potential to address many of humanity's most pressing problems—through, for example, fostering a world that is less sick, less hungry, more productive, better educated, and better prepared to thwart the effects of climate change—this promise comes with risks of entrenched and amplified social inequality.[115]. AI grounded in non-representative or biased data can entrench existing social and economic inequities, with AI systems reproducing the representation gaps and biases of the data sets used to train them.[116]. Already-dominant technology firms can use AI to further entrench their economic and social power or by governments to violate citizens' privacy and other human rights. A lack of transparency and accountability can compound AI's negative consequences as such systems are scaled up[117].

The broader use of AI, and more generally EDT, requires the involvement of different sectors and acknowledging the intersectionality of crucial factors that may play a role in their successful implementation. Gender equality and social inclusion are vital aspects of EDT for several reasons. Therefore, making these more conscious and central to their identities and activities is crucial.

Developing economies often face significant disparities in digital access and skills between genders. The new technologies may build upon and exacerbate existing inequalities—both within developing countries as well as between developing and more developed regions[118]. Promoting gender equality in EDT helps bridge this digital gender divide by ensuring that women and girls have equal opportunities to access and utilise them. Similarly, new technologies are powerful tools to empower marginalised communities in developing countries. By promoting social inclusion, these platforms ensure equal access and expression in the digital space for people from marginalised backgrounds, including minorities, people with disabilities, and other key populations. Digital technologies offer opportunities to bridge the disability digital divide and address longstanding issues of accessibility, inclusive and innovative design and digital inequality for persons with disabilities.[119]. Equality and inclusivity can foster economic empowerment, social mobility and the expansion of diverse voices. It can also lead to developing context-specific solutions, new business models, and technological advancements that address local challenges and needs.

There is evidence to suggest that African nations are experiencing a transformative "feminisation" of technology entrepreneurship[120]. Vibrant startup ecosystems that support women are emerging in Kenya, Nigeria, and South Africa, with North Africa catching up[121]. According to the 2022 Mastercard Index of Women's Entrepreneurship (MIWE), women in Sub-Saharan Africa continue to defy the odds, making their mark as vital economic contributors with a significant 'women's business ownership' (over 25%) of all local businesses. In Egypt, women are adopting AI technologies to engage in ride-sharing platform services as drivers, unprecedented in the country's male-dominated taxi-driving culture. It empowers women by improving their ability to provide for their livelihoods, breaking down social taboos, and using digital technologies to ensure their safety.[122].

Gender equality and social inclusion (GESI) are integral to achieving sustainable development goals in developing economies. EDT can contribute to various areas, including health, education, governance, and environmental sustainability. By ensuring GESI in these platforms, efforts towards sustainable development can be more comprehensive, equitable, and effective. The study analysed EDT to ascertain if GESI principles were taken on board.

4.2 Gender Equality Analysis

Representation and Participation

Gender gaps in user participation and engagement with EDT highlight disparities in how individuals of different genders interact with and benefit from these technologies.[123] Efforts to improve gender representation in EDT include promoting equal access to education and training, fostering supportive and inclusive tech environments, challenging gender biases in algorithms, increasing women's leadership and decision-making roles, and promoting gender diversity in tech organisations and conferences. According to Deloitte Global, by 2022, leading global tech businesses would have an average of roughly 33% female employees, up just over 2% from 2019. In the tech sector, there is a sizable gender gap, with fewer women holding influential positions. This lack of diversity may skew technology development. EDT may neglect or under-address the demands of women if their varied viewpoints and experiences are not accounted for, resulting in gender-based discrimination in their design, functionality, and effects.

Tech hubs like *LakeHub*[124] in Kenya, run programs that pay special attention to developing tech skills in young women by offering scholarships for training. The *Institute of Emerging Technologies South Africa (IETSA)*[125] is a similar startup to accelerate EDT towards achieving sustainable development. These initiatives bridge the participation and representation gaps identified earlier in the development and end-use of EDT. Both startups have strong female representation in their management and showcase the increasing gender representation in EDT, which stands to unlock economic opportunities for women, contribute to their empowerment, close the gender pay gap, and foster economic growth and development.

EDT in education like *Kidato*, whilst not purely focused on STEM, introduces learners to tech use in their education, which contributes to diverse perspectives and talent in developing and utilising EDT. Women are making progress in the tech sector thanks to attempts to promote gender equality, albeit with slow

progress and few initiatives (BairesDev, 2022). The approach to increasing the number of women in technology- development and use should be worldwide. A holistic approach is required to close the gender gap in these industries and society.

Critical in the move towards gender representation in EDT is the realisation that diverse viewpoints and experiences help people

[115] Gwagwa et.al., (2020)
[116] *Ibid*
[117] Gwagwa, A., (n.d)
[118] Gwagwa et.al., (2020)
[119] World Bank, (2016)
[120] Mastercard, (2022)
[121] *Ibid*
[122] Gwagwa, (2020)
[123] Ferrein and Meyer (2012)
[124] https://saaiassociation.co.za/
[125] https://lesira.co.za/service/smart-water-meter/

be more inventive and creative, which leads to more effective solutions. Gender diversity ensures that women's distinctive views and insights are considered when developing new technologies, resulting in more inclusive and successful solutions.

Content and Services

Assessing gender biases in platform content and algorithms involves examining the presence of discriminatory or biased practices that may disproportionately affect individuals based on their gender. Evaluating gender-sensitive services and features in EDT involves assessing the extent to which these technologies consider and address the needs, preferences, and experiences of individuals of different genders.[126]

Any underrepresentation or stereotypical portrayals may reinforce gender biases. Additionally, discriminatory practices, such as gender-based advertising, reinforce traditional gender roles or exclude certain genders from specific opportunities. EDT should consider the visibility of women in prominent positions, leadership roles, and decision-making processes within the platform. Examining how options are presented and whether they use biased language or perpetuate gender stereotypes is critical to ensure a projection of equality and inclusion.

EDT must also consider the diverse aspects of user experience and customise their services accordingly. Developers should exercise caution to ensure that opportunities for users to personalise their experience do not reinforce gender biases or limit opportunities based on gender but provide options for diverse user preferences.

Economic Opportunities

Analysing gender disparities in income generation and monetisation of EDT involved examining the differences in earning opportunities, financial rewards, and economic empowerment for individuals of different genders.[127] As EDT such as AI, machine learning, and robotics continue to advance, they can impact different aspects of society, including the workplace, healthcare, and education. However, if not carefully developed and implemented, these technologies can perpetuate or exacerbate existing gender biases and discrimination.[128]

It is crucial to analyse the potential and accessibility for users of different genders to make money from their contributions to EDT platforms, like app stores, e-commerce sites, sites for publishing content, and sites for the gig economy. Developers should consider whether impediments, discriminatory practices, or gender prejudices affect the earning potential of different genders. There should be an assessment of the differences in access between men and women to training programmes, chances for skill development, and capacity-building programmes in the developing technological industries. Further, how different genders access these tools may affect their ability to earn money and monetise their ideas. Linked to the aforementioned is an evaluation of social and cultural factors influencing gender disparities in income generation. These factors may include societal norms, stereotypes, and biases that affect career choices, negotiation skills, and access to networks and opportunities within emerging technology sectors.

Opportunities for women-owned businesses in EDT are expanding, offering new avenues for innovation, growth, and empowerment. While the tech industry has traditionally been male-dominated, efforts to promote diversity and inclusion have paved the way for women entrepreneurs to participate and thrive in this dynamic sector. *For example, Chichwa*,[129] an e-commerce platform aiming to connect women and youth in the informal trade with a wider range of consumers for their products has tailored its use based on the experiences of women and youth-owned SMEs. *Wasoko* (formerly *Sokowatch)*[130] is another platform that has provided an opportunity for women retailers to connect with consumers of their products and an avenue to grow their small businesses by fronting their goods on credit. *Agrikool*[131], although not directly highlighting gender aspects, seeks to provide an easier avenue for farmers to reach their customers by bridging the gap in terms of negotiating the best prices and handling all the relevant logistics. This presupposes the inclusion of farmers who would otherwise not be able to reach their targeted market due to being in rural areas.

4.3 Social Inclusion Analysis

Accessibility and Digital Divide

The accessibility of EDT and the digital divide are closely intertwined. While EDT have the potential to enhance connectivity, knowledge sharing, and opportunities, they can also exacerbate existing disparities in access and usage. The digital divide refers to the gap between individuals or communities accessing and effectively using digital technologies and those not.

The digital skills gap refers to the disparity between the demand for digital skills in the workforce and the available supply of individuals with those skills. This gap has significant implications for social inclusion, as it affects individuals' ability to access opportunities, participate in the digital economy, and fully engage in the digital society.[132] The digital skills gap affects educational opportunities and learning outcomes. As technology becomes integral to modern education, individuals lacking digital skills may need help accessing online learning resources, participating in digital classrooms, or engaging in distance education programs. A lack of required skills can exacerbate educational inequalities and limit the ability of individuals to acquire the knowledge and skills needed for personal growth and success.[133]

Further, the digital skills gap can create an intergenerational divide, particularly between the younger and older generations. More youthful individuals who have grown up with technology may have a natural advantage in digital skills, while older individuals may struggle to acquire or adapt to new technologies[134]. This divide can result in reduced intergenerational communication, limited access to digital services for older adults, and the potential exclusion of older individuals from digital platforms and opportunities. *M-Shule* is an online platform that addresses the digital skills gap and promotes social inclusion by providing different courses for learners of all ages, independent of their device type. Learners

[126] http://www.saaqis.org.za
[127] Open Data South Africa (2022)
[128] https://www.naked.insure/blog
[129] https://www.chichwa.co.ke/home/
[130] https://wasoko.com
[131] https://agrikool.com
[132] https://dsgi.wiley.com/
[133] https://www.sappi.com/sappi-saiccor-expansion-and-upgrade
[134] Mastercard, (2022)

can access the platform from all phones, not just smartphones. The platform incorporates digital skills and literacy into formal education systems at all levels, equipping future generations with the necessary skills.[135]

The use of EDT requires access to affordable broadband connectivity and dependable Internet infrastructure. However, there are still significant inequalities in the development of infrastructure, especially in rural and distant locations or in economically underprivileged groups[136]. Out of the 200 innovation centres mapped in 47 counties in Kenya, 46% of these centres are in Nairobi, skewing those in the rural areas and other cities[137]. Limited access to high-speed Internet prevents people and companies from fully using the new technology and participating in the digital economy. To compound matters, the cost of accessing and using modern technology, such as smartphones, laptops, and software applications, can be a substantial obstacle for people with limited financial resources. Preventing marginalised people from using and benefiting from new technology due to high device costs, subscription fees, and data plans can widen the digital divide. *Mawingu Networks* is a startup that seeks to bridge this gap by providing affordable wireless Internet hotspots.[138]

However, the reality is that most of the population still needs help to make ends meet, and Internet access tends to fall to the bottom of the priority list.

Cultural and Linguistic Diversity

Embracing cultural and linguistic diversity in EDT is a matter of social inclusion and a driver of innovation, creativity, and sustainable development. By valuing and integrating diverse perspectives, cultures, and languages, EDT can better serve the needs of global populations, foster cross-cultural understanding, and contribute to a more inclusive and equitable digital future.[139]

For instance, language options and support for diverse communities in EDT are crucial in ensuring inclusivity and accessibility. *Ujuzi Kilimo*[140] in Kenya provides farmers with information on different farming technologies in English and Kiswahili, the national language. Similarly, *Abalobi* [141] app is designed for small-scale fisherfolk and is available in several languages in Southern and Eastern Africa and the rest of the world. This localisation and bilingual support offered by the platform enables individuals from different linguistic backgrounds to access and benefit from these technologies. The availability of relevant and localised content in EDT is crucial for accessibility. Language barriers and limited content diversity can exclude individuals whose primary language is not widely supported or who belong to underrepresented communities. Ensuring linguistic and cultural diversity in EDT can enhance inclusivity and bridge the digital divide. *M-Lugha*[142] is a multilingual app that supports basic literacy and numeracy skill acquisition in the native language of pastoralist communities in Kenya. The multilingual feature ensures inclusion for a wide range of users despite their cultural context. Conversely, most EDT platforms like Iprocure, whose main target is the rural population, do not provide language options during the initial setup or allow users to switch between languages, thus limiting accessibility and user experience.[143]

It is essential to include a wide range of languages, considering both widely spoken languages and languages specific to certain regions or communities.

Privacy and Data Protection

Vulnerable populations are often at higher risk of data breaches and privacy violations due to limited resources, lack of awareness, and dependence on technology for essential services.[144]. Implementing robust security measures to protect sensitive data and minimise the risk of unauthorised access or breaches is essential. Safeguards should be in place to mitigate the potential harm caused by data breaches, particularly for vulnerable individuals. EDT often collect and process vast amounts of personal data, raising concerns about privacy and security. Mishandling data or misusing it can lead to gender-based discrimination. For instance, if sensitive health data related to reproductive health or gender identity is leaked or shared without consent, it can have severe consequences for individuals who already face societal discrimination.

More equitable and inclusive digital environments can be created by assessing and addressing the impact of data collection and usage practices on vulnerable populations in EDT. Protecting vulnerable populations' privacy, autonomy, and well-being and empowering them to actively participate in shaping data practices that affect their lives is essential. EDT should comply with ethical data gathering and usage standards to prevent the exploitation of vulnerable groups. The use of data must be responsible and open to avoid harm, stigmatisation, or prejudice against individuals or communities. It is essential to establish ethical frameworks, conduct rules, and governance systems to ensure that data practices uphold social values and protect the rights and welfare of vulnerable groups.

Consent procedures and privacy controls must be clear and uncomplicated. Users must know the types of data collected, its purposes, its use, and who will have access. Individuals can better decide whether or not to agree when privacy regulations and user interfaces are transparent.[145]. Additionally, consent requests should be in plain, unambiguous language that steers clear of technical legalese. The language should be clear to users regarding the extent and implications of their consent and simple enough for those with different levels of digital literacy to understand. *DigiCow*[146], for instance, is an App in Kenya for dairy farmers with information on how to care for their animals to maximise production and profit.

The developers have invested in user education and awareness on their platform to help individuals understand the importance of privacy controls and consent mechanisms. They provide clear information about the value of privacy, the implications of data sharing, and how to exercise control over personal information. *HaloCare*[147] is based in South Africa and focuses on chronic disease management. They have gone a step further to outline measures taken to ensure reduced incidences and effective handling of data breaches. Such measures inspire confidence in users and empower them to make informed decisions.

[135]https://www.mshule.com
[136] UNDP, (2020)
[137] *Ibid*
[138]https://mawingu.co
[139] https://fingo.fi/wp-content/uploads/2021/01/innovation-ecosystem-kenya_0.pdf
[140] https://www.ujuzikilimo.com
[141] https://abalobi.org
[142]https://m-lugha.com
[143]https://iprocu.re
[144] Nord, Riggio, and Paliszkiewicz, (2017); Bailur and Masiero (2017).
[145] Gonzales et.al, 2015; Kulkarni and Ghosh, 2021.
[146] https://digicow.co.ke/
[147] https://www.halocare.co.za/

4.4 Policy Areas for GESI in Emerging Digital Technologies

Addressing GESI barriers requires a multi-faceted approach. Implementing comprehensive digital inclusion programmes that give underprivileged people access to devices, connectivity, and training is crucial. These initiatives must concentrate on solving infrastructure constraints, digital literacy gaps, and economic hurdles.

Engaging with neighbourhood stakeholders, community organisations, and non-profit organisations can assist in developing solutions tailored to the underserved populace's needs. Partnerships with tech firms, academic institutions, and governmental organisations can make it easier for these groups to access resources, become trained, and receive support.

Governments and service providers should lower the financial obstacles to using these technologies by offering impoverished populations options for data plans, Internet connectivity, and subsidised or inexpensive gadgets.

It is critical to implement customised digital skills training programmes that cater to the unique requirements of underserved populations. These initiatives should emphasise developing fundamental digital literacy, fostering critical thinking, and offering chances to advance knowledge of emerging technology.

Localised applications and ensuring the availability of culturally appropriate information can improve accessibility and engagement for underserved areas.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Discussion

EDT/X-Data applications are poised to impact Kenya and South Africa significantly by unlocking new opportunities for innovation, improving the quality of life and fostering socio-economic growth. The applications can potentially solve current and emerging socio-economic problems, including unemployment, insecurity, poverty and corruption. Their development has become a source of solutions through data and intelligence across various sectors, including education, health, agriculture and governance. For instance, IoT and AI support improving health through disease mitigation and healthcare coverage, while blockchain supports food security and sustainability by enabling the detection of counterfeit seeds and enhancing accountability and transparency in governance and public service delivery.

Kenya and South Africa have many economic opportunities in all sectors coupled with youthful, digitally enthusiastic populations, making digitally-enabled socio-economic development a high priority for both countries. The EDT/X-Data ecosystems are a driving force for innovative, inclusive and sustainable growth. EDT/X-Data-based applications can provide real solutions that stimulate job creation, contribute to poverty mitigation, reduce inequality and facilitate the delivery of goods and services.

The primary challenge for Kenya and South Africa is the low level of EDT/X-Data research, development and implementation of solutions. The two countries need more activist policies that promote research, capacity building, innovation and implementation of EDT/X-Data and complementary technologies that support productive and inclusive solutions. Such policies must target all stakeholders to foster robust and integrated ecosystems.

Kenya and South Africa rank high among the sub-Saharan African countries in the Government AI Readiness Index. However, in Kenya, the education system remains weak in supporting the development of new EDT and EDT/X-Data-based applications as few universities offer EDT/X-Data-related courses at Masters and PhD levels. Further, while many researchers and innovators have benefited from some capacity-building activities in big data, analytics and IoT, few have built their capacity in AI and GIS, and even fewer in machine language. On the other hand, in South Africa, the education system is steadily building the capacity to support the EDT/X-Data ecosystem through related courses and programmes, such as those focusing on 4IR, AI and robotics. However, the gap between the academic qualifications and the dynamic demands of the job market persists and has necessitated specific and targeted on-the-job training to match skills with job demands.

The South African government acknowledges EDT/X-Data as a modern driver of economic development. In its January 2023 statement, the ruling African National Congress party identified advancing digital technologies, such as big data, artificial intelligence, and machine learning, as one of the economic growth and development policy priorities that can enhance the delivery of public services to keep abreast of changing economies and societies[148]. Big data and analytics platforms will help government institutions to respond and change their processes to improve service delivery.

Even though EDT have the potential to drive long-term economic growth and lead to the modernisation of economic activities across sectors, the digital divide continues to grow between large formal businesses and micro enterprises in the informal sector, young and old, men and women, rich and the poor, urban and the rural populations, and between the better and less educated. Appropriate policies accompanied by the

Table 4.1: GESI Policy Gaps and Recommendations for EDT

Policy gaps and challenges	Recommendations for EDT Providers	Policy Recommendations for Governments and Regulatory Bodies
○ Identification of regulatory and policy gaps related to gender equality and social inclusion ○ Examination of challenges in enforcing existing policies	○ Strategies for promoting gender equality and diverse representation ○ Measures to enhance accessibility and address the digital divide ○ Steps to ensure privacy, data protection, and security for all users	○ Proposed regulations to promote gender equality and social inclusion ○ Strategies for fostering a supportive environment for emerging digital technologies ○ Initiatives to bridge the digital divide and promote digital literacy

[148] www.turbofuture.com

provision of necessary amenities such as affordable power, Internet, education, road network and finances are needed to bridge these gaps and imbalances to enhance gender equality and social inclusion. These would align with the Africa Union's Science, Technology and Innovation Strategy for Africa (STISA) 2024, which envisages enhancement of technical competencies, investment in STI infrastructure, promotion of innovation and entrepreneurship and development and implementation of favourable national and regional STI policies.

The lack of adequate funding sources for research and innovation within the EDT/X-Data ecosystem has either denied or delayed researchers and innovators in generating knowledge, protecting their outputs and commercialising their products. Sometimes, they lose their inventions or exchange them for undervalued compensation from capable individuals or organisations. To adequately support the researchers and innovators in the EDT/X-Data ecosystem, Kenya and South Africa must implement the STISA 2024 target of investing at least 1% of the Gross Domestic Product (GDP) in R&D. The 2030 Agenda for Sustainable Development and the African Union Agenda 2063 both restate the R&D investment target recognising that R&D capabilities are enablers for technology-driven economic transformation.

5.2 Key Findings

Education

There are post-graduate programmes in EDT-related subjects in both countries. South Africa has a steady growth in dedicated programmes in AI, machine learning and data analytics, while there are upcoming degree programmes in Kenya. A range of additional training and curriculum offerings are available in both countries through the formal public education system, the TVET and SETAs, and by private providers. In both countries, the public school education curriculum now includes elements of coding and robotics. However, there are concerns surrounding graduates' quality and employability in both countries, calling for curriculum upgrades and linkage with industry.

Research and innovation

Kenya and South Africa's EDT/X-Data ecosystems have increasing levels of research, some of which progress up to commercialisation. Research is predominately occurring in health, agriculture, and fintech. The two countries rank highest within the continent on allocation to R&D as a percentage of the GDP: Kenya at 0.69% of GDP and South Africa at 0.62%. However, the most significant proportion of R&D funding in Kenya comes from foreign sources, while more than 50% of South Africa's comes from government sources.

Significant and deliberate efforts towards the commercialisation of research are evident in both countries, although it has proven difficult due to insufficient support frameworks. Kenya hosts R&D centres of large multinational firms such as Microsoft and IBM. South Africa's research output in EDT/X-data based on the number of journal publications is the highest in Africa, with Kenya significantly behind.

Implementation and use of Emerging Digital Technologies

Kenya and South Africa have digitally enthusiastic populations ready to embrace new and emerging solutions to their socio-economic problems. Both countries have a high adoption rate and use of EDT-related technologies, especially in the private sector. They find use across multiple sectors, especially agriculture, health and fintech. However, most of the EDT in use in both countries are imported. Kenya and South Africa have vibrant startup and incubation hub cultures, with a visible presence of venture capital funders. In South Africa, some companies have avoided the startup "Valley of Death" and been operational for over ten years. The success of these AI-based startups is not surprising, as research on AI and applications has been ongoing in South Africa since the 1970s.

Challenges

Both countries face similar challenges in the EDT/X-Data ecosystem. These include:

(a) *Skills and capabilities* – A significant lack of digital skills and literacy is attributed to the quality of primary and secondary education and Internet and technology access. Access can be linked to the broader economic disparities in both countries.

(b) *Funding* – While South Africa enjoys higher levels of government funding and most likely private sector support for firms and organisations implementing EDT-related applications (data was not readily available to confirm this), lack of funding remains a significant constraint impacting education, research, innovation and commercialisation.

(c) *Intellectual property and commercialisation* – Although both countries had high levels of research on EDT-related technologies, there were relatively low levels of commercialisation.

(d) *Gender Equity and Social Inclusion* – Severe GESI imbalances were evident in the EDT/X-Data ecosystem, including geographical exclusion, gender disparity, and underrepresentation of marginalised groups such as persons with disabilities.

(e) *Governance* – Clear regulatory and legal frameworks for EDT/X-Data are absent, making it difficult to align them within traditional sectors or line ministries to access funding and supportive infrastructure and to secure intellectual property protection for innovations.

(f) *Infrastructure* – Kenya faces infrastructural challenges with inadequate and not easily accessible laboratories, equipment, connectivity and datasets (big data).

Opportunities

Kenya and South Africa have placed Science, Technology and Innovation strengthening on top of their political agendas with Kenya's National Development Plan, Vision 2030, making STI a key pillar of success. Both countries have updated their STI policies in recent years. South Africa continues to benefit from a national interest in the 4IR. The PC4IR was significant in providing a national mandate for research and action in AI and data analytics.

Both countries' education systems are more robust than other African countries and continue to mature. The two countries have high numbers of graduates and post-graduate programmes that are research-intensive. South Africa benefits from a high level of research funding availability from the government. Both countries' startup culture and history have enabled private companies to roll out these technologies. Further, both countries are moving towards more agile and

facilitatory regulatory frameworks. They have a high level of linkages (networks and partnerships), especially between research community members. In particular, through networks and partnerships, South Africa has recently set up an industry association for AI professionals.

5.3 Recommendations

General Recommendations

General recommendations from the study and applicable to both countries include:

(a) Governments to increase and introduce dedicated funding streams to support homegrown research and technology development in the EDT/X-Data space;

(b) Develop and implement dedicated strategies to commercialise EDT/X-Data research products;

(c) Review and improve the existing policy and regulatory frameworks to be more facilitatory and agile; and

(d) Increase the number and types of stakeholders in the EDT/X-Data innovation ecosystem.

Recommendations on Gender Equity and Social Inclusion

To improve on Gender Equity and Social Inclusion from the development and use of EDT/X-Data, the study recommends that EDT developers and providers must employ strategies that:

(a) Promote gender equality and diverse representation;

(b) Enhance accessibility and address the digital divide; and

(c) Ensure privacy, data protection, and security for all users.

Further, governments and regulatory bodies should:

(a) Adopt affirmative strategies to promote gender equality and social inclusion;

(b) Advocate for targeted calls for female researchers and innovators in the EDT/X-Data space;

(c) Develop and implement policies and strategies that foster a supportive environment for research and innovation on EDT/X-Data in all geographical areas while ensuring equal accessibility to emerging opportunities by all; and

(d) Establish initiatives to bridge the digital divide and promote digital literacy.

Recommendations for Kenya

Researchers and innovators should:

(a) Strengthen linkages with the private sector and ensure demand-driven research and innovation;

(b) Develop an innovation platform to connect new technological solutions with industry players;

(c) Adopt the culture of learning from failure and working collaboratively;

(d) Enhance research networks to ensure information sharing, especially of the latest technological developments; and

(e) Strengthen mentorship and coaching programmes to support the emerging generation of scholars, researchers and innovators.

Further, policymakers should address the following areas:

(a) Capacity building: Develop policies to promote the training of individuals in EDT/X-Data to build a skilled workforce capable of developing and analysing EDT/X-Data-based applications and solutions.

(b) Data collection and sharing: Develop policies to regulate the collection, sharing, and use of data, including X-Data, that ensure ethical and legal collection of data that is shared in a way that maximises its benefits to the subjects and other stakeholders while protecting privacy and confidentiality.

(c) Incentives and funding: Develop policies to incentivise research and innovation and the adoption and use of EDT and X-Data. These include the provision of funding or tax incentives for stakeholders who invest in these technologies, as well as establishing prizes or awards for innovation and best practices in using EDT and X-Data.

(d) Intellectual property: Simplify the patenting process and create awareness among the stakeholders, especially researchers and innovators.

(e) Sensitisation: Adopt EDT/X-Data to inform policy-making processes and build the capacity of all stakeholders on the importance of EDT and X-Data.

(f) Public-private partnerships: Develop policies to promote public-private partnerships to support the development and application of EDT/X-Data solutions, including the development of joint initiatives between government agencies, private sector companies, and civil society organisations, as well as the establishment of regulatory frameworks and standards to guide these partnerships.

Recommendations for South Africa

Researchers and innovators should:

(a) Intensify efforts to bridge the existing skills and capability gaps, for example, through enhanced advertisement and marketing of available courses and programmes and provision of scholarships.

(b) Mobilise researcher networks to gain access to datasets and enhance training on data mining and scraping.

Finally, policymakers should address the following areas:

(a) National Research Fund and related agencies to provide spaces for information sharing;

(b) Introduce funding streams for EDT/X-Data-related research and commercialisation efforts;

(c) Increase the levels of agile regulation by enhancing information sharing, multi-stakeholder engagement and cross-ministry activity;

(d) Recognise the needs and requirements of different types of users within the innovation ecosystem, notably the difference between professionals and end users and

(e) Set up multi-stakeholder engagement platforms dedicated to sharing information and networking opportunities for those working in different EDT-related spaces.

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Appendix A – Survey Instrument for Researchers and Innovators

The University of Nairobi (Kenya) and the University of Johannesburg (South Africa) are collaboratively implementing a project titled, "Ecosystem Strengthening as a Catalyst for International Collaborative Development of Emerging Digital Technologies and X-Data Applications Tackling Socio-Economic Challenges in Kenya and South Africa", funded by UKAID through Research and Innovation Systems in Africa (RISA) Fund. The project aims at documenting the status and developing a deep understanding of the EDTs/X-Data ecosystems, build capacity and support networks for researchers and innovators.

EDTs refers to Emerging Digital Technologies such as the Artificial Intelligence, Blockchain, Big data/Big data analytics, Machine Learning and Internet of Things. On the other hand, X-Data refers to four overlapping data categories; big data, open data, user-generated data and real-time data.

You have been identified as a researcher and/innovator with interest in the EDTs/X-Data ecosystem, and you are requested to support the project by completing this questionnaire.

Notes:

(a) The questionnaire does not require you to fill any identification information; and

(b) The information gathered will be treated with confidentiality and integrity, and will be used solely for the purposes of this study.

* Indicates required question

1. Name of your organization *

2. Your designation *

3. Your gender *

- Male
- Female

4. Your highest academic qualification *

- PhD
- Masters Degree

5. Your years of experience in academia and/or research *

- Below 5
- 6 - 15
- 16 - 25
- Above 25

6. Which of the following Emerging Digital Technologies (EDTs) is your research based on? (you may select more than one) *

- Artificial Intelligence
- Internet of Things
- Blockchain
- Machine Learning
- GIS
- Other:

7. Which of the following X-Data is your research based on? (you may select more than one) *

- Big data
- Open data
- User-generated data
- Real-time data
- Other:

8. a) Have you undertaken any course/training on any EDT and/or X-Data? *

- Yes
- No

b) If yes, please list the EDTs/X-Data covered by the course: *

9. a) How many journal publications do you have that are directly related to EDTs/X-Data? *

b) Please list your journal publications related to EDTs/X-Data in the last five years: *

10. In the last five years, how many local workshops or conferences with focus on your selected EDTs/X-Data have you:

- Only attended?
- Presented?
- Organized?

11. Which sector(s) of the economy does your research target? (e.g. Agriculture, Health etc.)

12. At what stage are your current research activities? (select all that apply)

- Just starting
- Ready for publication/published
- Carried out proof of concepts
- Ready for deployment/commercialization

13. a) Are you collaborating with industry in your current research activities?

- Yes
- No

b) Have you collaborated with industry in any of your past research activities?

- Yes
- No

14. a) Are you collaborating with other universities/research institutions in your current research activities?

- Yes
- No

b) Have you collaborated with other universities/research institutions in any of your past research activities?

- Yes
- No

15. a) Have you patented or copyrighted any of your research outputs related to EDTs/X-Data?

- Yes
- No

b) If yes, kindly provide the patent/copyright title(s)

c) Are you likely to file for a patent or copyright for the output of your current research activities in the next one year?

- Yes
- No

16. a) Do you have research funding for your current research activities

- Yes
- No

b) If yes, from which source?

- Government
- Local foundation
- Foreign foundation

- Development partner(s)
- Other:

c) To what extent are sources of research funding available for your work?

- There are no sources of funding
- There are few sources of funding
- There are adequate sources of funding
- There are plenty of sources of funding
- I am not sure

17. What are the THREE biggest challenges (in order) that you face in carrying out research on EDTs/X-Data?

18. What are the THREE biggest opportunities/motivations (in order) that have boosted your research work on EDTs/X-Data?

19. a) Are you currently teaching post-graduate students in the area of EDTs/X-Data?

- Yes
- No

b) If yes, how do you rate, on average, the quality of the students (ability to grasp concepts, think independently, carry out quality supervised research)?

- Very poor
- Poor
- Acceptable
- Good
- Very good

For questions 20 and 21 please indicate the extent to which you agree or disagree with the given statement.

20. I have the necessary equipment/tools to carry out research work in the area of EDTs/X-Data.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

21. Current government policies are supportive of research on and application of EDTs/X-Data.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

22. Please suggest the type of policies you would like to be put in place to support the development and application of EDTs/X-Data in Kenya

Appendix B – Survey Instrument for Policy-Makers, Funders and Decision-Makers

The University of Nairobi (Kenya) and the University of Johannesburg (South Africa) are collaboratively implementing a project titled, "Ecosystem Strengthening as a Catalyst for International Collaborative Development of Emerging Digital Technologies and X-Data Applications Tackling Socio-Economic Challenges in Kenya and South Africa", funded by UKAID through Research and Innovation Systems in Africa (RISA) Fund. The project aims at documenting the status and developing a deep understanding of the EDTs/X-Data ecosystems, build capacity and support networks for researchers and innovators.

EDTs refers to Emerging Digital Technologies such as the Artificial Intelligence, Blockchain, Big data/Big data analytics, Machine Learning and Internet of Things. On the other hand, X-Data refers to four overlapping data categories; big data, open data, user-generated data and real-time data.

You have been identified as a Policy/Decision maker and/or Funder with interest in the EDTs/X-Data ecosystem, and you are requested to support the project by completing this questionnaire.

Notes:

(a) The questionnaire does not require you to fill any identification information; and
(b) The information gathered will be treated with confidentiality and integrity, and will be used solely for the purposes of this study.

* Indicates required question

1. Name of your organization *

2. Your designation *

3. Your gender *

- Male
- Female

4. How do you classify yourself? *

- Policy/Decision maker
- Funder
- Both

5. Which of the following Emerging Digital Technologies (EDTs) are you involved in? (you may select more than one) *

- Artificial Intelligence
- Internet of Things
- Blockchain
- Machine Learning
- GIS
- Other:

6. Which of the following X-Data are you involved in? (you may select more than one) *

- Big data
- Open data
- User-generated data
- Real-time data
- Other:

7. Which among the following do you collaborate with in your activities? (you may select more than one)

- Industry
- Universities
- Innovation hubs
- Other:

8. Do you support researchers/innovators to secure their EDTs/X-Data related intellectual properties through patent, copyright or other means?

- Yes
- No

9. What are the THREE biggest challenges (in order) that you face in supporting research and innovation on EDTs/X-Data?

10. What are the THREE biggest opportunities/motivations (in order) that drive you to support research and innovation on EDTs/X-Data?

For questions 11 and 12 please indicate the extent to which you agree or disagree with the given statement.

11. Research outputs are adequately utilised to inform decisions and policies that directly or indirectly affect EDTs/X-Data.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

12. Current government policies are supportive of research on and application of EDTs/X-Data.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

13. Please suggest the type of policies you would like to be put in place to support the development and application of EDTs/X-Data in Kenya: