

AI FOR AFRICA: ARTIFICIAL INTELLIGENCE FOR AFRICA'S SOCIO-ECONOMIC DEVELOPMENT



AUDA-NEPAD
AFRICAN UNION DEVELOPMENT AGENCY

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The African Union (AU) is a continental body consisting of all 55 countries on the African continent. It was established on 26th May 2001 in Addis Ababa, Ethiopia, and launched on 9th July 2002 in South Africa¹ with the aim of replacing the Organisation of African Unity (OAU). The most important decisions of the AU are made by the Assembly of the African Union, a semi-annual meeting of the Heads of State and Government of its member states. The AU's secretariat, the African Union Commission, is based in Addis Ababa, Ethiopia.

The AU was established following the 9th of September 1999 Sirte Declaration of the Heads of State and Governments of the Organisation of the African Unity (OAU). The AU is based on a common vision of a united and strong Africa and on the need to build a partnership between governments and all segments of civil society, in particular, women, youth and the private sector, in order to strengthen solidarity and cohesion amongst the peoples of Africa. As a continental organisation, it focuses on the promotion of peace, security, and stability. The development work of the AU is guided by the AU Agenda 2063, which is a 50-year plan to harness Africa's comparative advantage to deliver on the vision of "The Africa We Want".

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¹ About the African Union <https://au.int/en/overview>

AU High-Level Panel on Emerging Technologies Report: AIfor Africa: Artificial Intelligence for Africa's Socio-Economic Development

This Technology Report is the product of the African Union High Level Panel on Emerging Technologies (APET). It is part of a larger effort by the African Union Development Agency (AUDA-NEPAD) to promote knowledge and learning, share ideas, provide open access to its research, and contribute to development policy. The articles featured in the APET technology report is considered to have a bearing on the mission of AUDA-NEPAD, and its strategic objectives, as aligned to the AU Agenda 2063, which is a Pan African vision of an integrated, prosperous, and peaceful Africa, driven by its own citizens, representing a dynamic force in the international arena.

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© African Union Development Agency – NEPAD (AUDA-NEPAD)
230 15th Road, Randjespark, Midrand,
Johannesburg, 1685, South Africa

+27 11 256 3600
www.nepad.org

Twitter
[@Nepad_agency](https://twitter.com/Nepad_agency)

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African Union High Level Panel on Emerging Technologies (APET)

AUTHORS

1. African Union High Level Panel on Emerging Technologies;
2. APET Secretariat; and
3. African experts and researchers on Artificial Intelligence

APET CHAIR

Yaye Kène Gassama, Université Cheikh Anta Diop de Dakar, Senegal

PANEL MEMBERS

Abdallah Daar, University of Toronto, Canada

Berhanu M. Abegaz, African Academy of Sciences, Ethiopia

Francine Ntoumi, Fondation Congolaise pour la Recherche Médicale, Congo-Brazzaville

Karim Maredia, Michigan State University (MSU), East Lansing, Michigan, USA

Oye Ibidapo-Obe, (Late) Federal University Ndufu Alike, Ikwo (FUNAI), Nigeria

Rachel Chikwamba, Council for Scientific and Industrial Research (CSIR), South Africa

Roseanne Diab, Academy of Science of South Africa (ASSAf), South Africa

Shireen Assem, Agricultural Research Centre and Genetic Engineering and Biotechnology Research Institute (AGERI), Egypt

RESEARCH AND DRAFTING TEAM

Thomas Meyer (University of Cape Town), **Deshen Moodley** (University of Cape Town), **Nelishia Pillay** (University of Pretoria), **Vukosi Marivate** (University of Pretoria, Deep Learning Indaba), **Emma Ruttkamp-Bloem** (University of Pretoria), **Moktar Sellami** Direction du Development Technologique et de l'Innovation (MERS), **Sunday Ojo** (Tshwane University of Technology), **Sunday Asaolu** (University of Lagos), **Michael Zimba** (Mzuzu University), **Terence van Zyl** (University of Johannesburg), **Darlington Ahiale Akogo** (MinoHealth AI Labs), **Immaculate Motsi-Omojiade** (University of Birmingham), **Towela Nyirenda-Jere** (AUDA-NEPAD), **Diran Makinde** (late) (AUDA-NEPAD), **Aggrey Ambali** (AUDA-NEPAD), **Justina Dugbazah** (AUDA-NEPAD), **Lukovi Seke** (AUDA-NEPAD) **Barbara Glover** (AUDA-NEPAD), **Wasswa William** (Mbarara University of Science and Technology, Uganda)

APET SECRETARIAT

Aggrey Ambali – AUDA-NEPAD

Justina Dugbazah – AUDA-NEPAD

Barbara Glover – AUDA-NEPAD

Thelma Dlamini – AUDA-NEPAD

Chifundo Kungade – AUDA-NEPAD

Mahama Ouedraogo – African Union Commission

Monica Idinoba – Africa Union Commission

Hambani Masheleni – Africa Union Commission

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Tributes

Prof Calestous Juma

“For a whole generation, and maybe for future generations of leaders, he was an exceptional teacher and thinker as well as one of the shining lights of Africa in the intellectual sphere.” – **Dr Ibrahim Mayaki, AUDA-NEPAD**

“Those who had the pleasure of meeting him—or communicating with him online and off—will testify to his warmth, his love of learning, and his great generosity.” - **H. E. Uhuru Kenyatta, President of the Republic of Kenya**

“Calestous was a tireless champion for economic and social development in Africa. His legacy will live on through the fruits of his many years of work as an impassioned scholar, fearless advocate and mentor to students and policymakers around the world.”

“We have lost a brilliant mind who was dedicated to innovation, education and Africa’s prosperity.”

- **H.E. Paul Kagame, President of the Republic of Rwanda**

“Gifted with immense wit, charm, courage, humour and modesty—a rare combination, Professor Juma was a trusted advisor to Heads of State and Government throughout the world on critical issues affecting humankind today.”

- **The Common Market for Eastern and Southern Africa (COMESA)**

ProfDiran Makinde

Many people in Africa and around the world will long remember Prof. Oladiran Martin Makinde as a champion for harnessing Science, Technology and Innovation for better livelihoods of the peoples of Africa; a firm believer that Science, Technology and Innovation can co-evolve with regulations. But those of us who lived and worked with him nearly every day and will long ache with his passing, know Prof. Diran (as we popularly called him) by many other titles he held: Husband. Father. Brother. Grandfather. Director, mentor, advisor and many more.

He was the sunny, joyful person who lit every moment with his infectious smile whether you meet him in the corridors, staff kitchen, boardroom for meetings, but everywhere and always. He had an incredible ability to accommodate and work with people irrespective of their different viewpoints. He cherished life and life cherished him and everyone who met him, everyone who knew him will remember his invincible smile and contagious laugh.

A true gentleman with a great sense of life who lived up to the positive energy he chose to bring to those he interacted and interfaced with every single day. His wisdom and guidance were instrumental in the establishment of ABNE and the success that it continues to achieve to date are the outcomes of the firm building blocks he and others helped to put together 10 years

We have not yet come to terms with the passing away of Prof. Diran. We cannot know for certain as to why he left us this soon. But we remain comforted by the assurance that we will meet again one day. We pray for comfort, fortitude, and peace to all his loved ones

Prof Oyewusi Ibidapo-Oye

In December 2016, the late Professor Oyewusi Ibidapo-Obe was appointed a member of the African Union High level Panel on Emerging Technologies (APET) by the then Chairperson of the African Union Commission (AUC), H.E. Dr Nkosazana Dlamini Zuma. This began our journey with this eminent expert who we fondly called Prof Oye.

His wit, ambience and welcoming spirit is a feature he brought to APET that would not be soon forgotten.

Prof Oye's characteristic of sacrificing his time and energy for the continent was quite authentic – he did that with charm and joy and always had something to contribute to discussions. He was ever ready to offer to the panel suggestions of continental experts that can contribute knowledge to Africa's development.

We look back at his loving tribute to the late Professor Calestous Juma, and the joy with which he spoke of continuing his legacy – which he adequately fulfilled. Today, we remember someone whose legacy has influenced many far and wide; the youth especially were his heartbeat.

Prof Oye was passionate about sustaining Africa's indigenous knowledge and we at AUDA-NEPAD pledge to carry on with his ideas on effectively harnessing our indigenous knowledge in addressing continental challenges.

Prof Oye! Your life was a blessing, your memory a treasure, you are loved beyond words and missed beyond measure. The day we heard of your death; it was like a dream. Death is appointed unto us all, but we just couldn't accept that it was your time. In the few days to your death, you were actively with us, so it was so hard to take that you would be with us no more.

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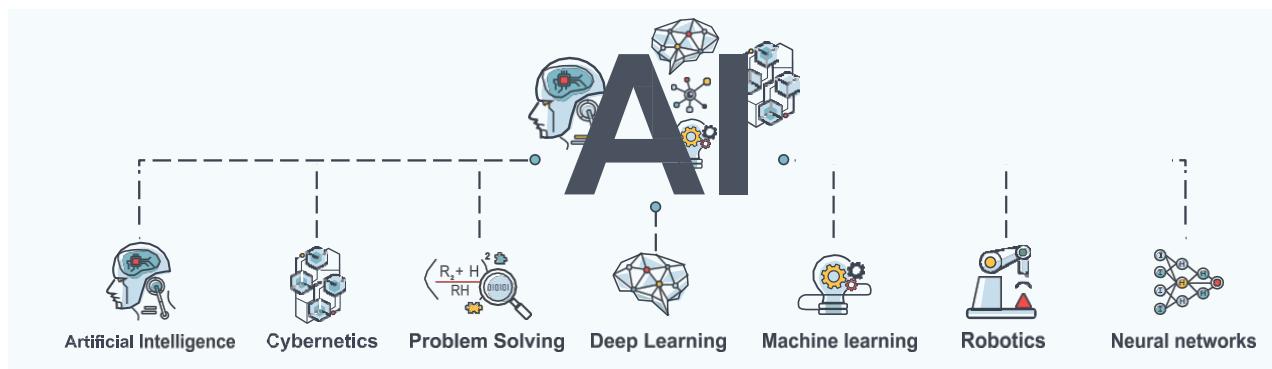
Acronyms

AUDA-NEPAD	African Union Development Agency - New Partnership for Africa's Development
AUC	African Union Commission
AI	Artificial Intelligence
AIST	Artificial Intelligence Science and Technology
AIT	Artificial Intelligence Technology
AMA	Artificial Moral Agent
AU	African Union
CAADP	Comprehensive Africa Agriculture Development Programme
CJDIET	The Calestous Juma Executive Dialogue on Innovation and Emerging
COVID-19	Technologies Corona Virus Disease 2019
ETAC	Emerging Technology Analysis Canvas
GDP	Gross Domestic Product
GPS	Global Positioning System
IoT	Internet of Things
KR	Knowledge Representation and Reasoning
LAWs	Lethal Autonomous Weapon Systems
MOOCs	Massive Open Online Courses
NLP	Natural Language Processing
OAU	Organisation of African Unity
PIDA	Programme on Infrastructure Development for Africa
PUST	Pan-African Union for Science and Technology
S&T	Science and Technology
SDGs	Sustainable Development Goals
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology, and Innovation
STISA	Science, Technology, Innovation Strategy for Africa
UAV's	Unmanned Aerial Vehicles

Executive Summary

There is a shared motivation among African and global policymakers to improve the livelihoods of the African people through socio-economic development aspirations known as the African Union's (AU) Agenda 2063 and the Sustainable Development Goals (SDGs). These socio-economic development aspirations are representative of the shared energy and excitement around the growth potential of African Member States. Recent projections have predicted that Artificial Intelligence (AI)-based technologies will potentially double the Gross Domestic Product (GDP) growth rate of African countries by 2035, regarding the long-term socio-economic impact of AI around the world. Therefore, this means that harnessing even a fraction of the AI technologies would significantly contribute to the socio-economic development of the African continent and alleviate poverty through some economic sectors. The key economic sectors of interest include agriculture, healthcare, public services, mining, industry, and financial services, which AI-based technologies, supported by appropriate policies, ethical and legal frameworks can significantly upsurge growth and development.

According to STISA-2024, African's Agenda 2063 and SDGs, Africa aspires to mobilise and promote the growth of a responsive AI-technology-based economic system for Africa continent. Hence, forward-thinking policymaking, innovative AI-based business start-ups, global AI technology partners, civil society groups, and international global stakeholders are needed to attain these aspirations. However, there are structural and systematic policy developments that Africa needs to adopt in order to advance a healthy AI-based economic system for the African continent. This means that the educational system must be adapted much faster towards an AI-focused education system with the view of creating employment opportunities for youth, especially among women and girls. Gender unsteadiness within STEM fields has been reported to show that less than 30% of women are in the global scientific research community. Furthermore, women are less than 22% in AI-related fields, more especially among researchers from French-speaking countries than English-speaking countries. Thus, African countries need to bridge these STEM gender issues. This imbalance will draw drastic consequences on the job market if this gap remains unaddressed.



The adaptation of AI technology into the African economy comes with inherent developmental challenges. Notably, there have been misperceptions spread against AI technologies. AI has been projected to be posing a grave and imminent danger to the future of humankind. For example, it has been predicted that unemployment and inequality may increase because of the adoption and implementation of AI globally; thus, contributing to massive unemployment and further contribute to levels of inequality. This is based on the fact that AI tools and AI-based artefacts may completely replace human activities in some sectors of the economy or develop into superior and uncontrollable beings. However, this line of thinking fails to appreciate the potential and massive benefits from AI technologies implementation in the African systems. In contrast, it will take some time before generalised AI (strong AI) machines, known as super-smart machines capable of functioning like humans, are fully developed and exploited.

Furthermore, AI-based technologies are already enhancing the education, commerce, banking, healthcare, agriculture, and mining sectors. Therefore, African governments need to embrace these challenges and opportunities by creating appropriate guidelines and policies such as legal, ethical, regulatory, safety and privacy frameworks. Consequently, different African Member States have been presenting numerous AI strategies and investing in harnessing the rollout of AI technology for the socio-economic development of their countries, however, more investment in AI technology is needed. Some areas are indicated below.

Policy and Regulations: African countries must develop AI-specific policies and strategies over the next five years. Presently, it is only Kenya that has established an AI task force focused on a national strategy, amongst all the AU Member States. Thus, African countries must form policy capacity, and further blueprint national, regional, and continental AI regulatory frameworks that suit the African context. Furthermore, there is a need to gutter investments toward prioritised solutions for AI-based development. The AU's Agenda 2063 and Convention on Cyber Security and Personal Data Protection could offer such a shared vision for African countries. It could help the countries forge collaborative platforms and networks in order to inform and grow AI-specific policies to at least 30 African countries over the next five years. There is also critical recognition to formulate policies and regulatory frameworks that best suit the African context, instead of the copy-and-paste of the made-in-the-North AI policy frameworks that do not address specific Africans' needs and opportunities. These priorities and directions of AI must be determined at national, regional, and continental levels to clear the way for innovation, restrain harm from the adoption of AI technologies and support human rights, safety, and privacy.

Skills and Infrastructure: There is a need to create a conduit of tertiary level education programmes specialising in AI, data science, and other interdisciplinary fields. Building skills and capacity for Africans can enhance an inclusive AI future and strength through the community as well as formalising AI training and recruitment of AI talent in Africa. For example, there could be the creation of 400 African PhDs in AI, data science, and other interdisciplinary fields over the next five years. This will enable and facilitate the formation of an appropriate AI infrastructure and capacity. In addition, this could further enhance the strength and agility of educational systems in order to seize the new digital opportunities and underpin investments in learning outcomes in machine learning, artificial intelligence, and data sciences in Africa. Moreover, there is a need to focus beyond PhDs, whereby African countries also target and invest in the youth at primary and secondary school levels through mentorship programmes for emerging leaders. These investments should be inclusive of women and girls so to capacitate the next generation of AI practitioners. Inclusion within Member States must guide the design of responsive and equitable AI skills and capacity building roadmap in Africa. Furthermore, there is a call to establish AI Centres of Excellence in each African country by 2030 that can assist in incubating ideas and fostering AI communities of practice in an interdisciplinary and inclusive manner.

Applications and Investments: There should be a collective investment by African Member States into collaborative innovation and research prioritising solution areas for sustainable development in Africa. Thus, the implementation of AI applications must be addressing people's needs on the ground and the potential benefits of AI translated into real impact for African citizens. There should be a ground-up approach of collaborative ideas and practical utilisation of AI that enhances access to healthcare, agriculture, public services, banking, and education. This is particularly imperative for the most vulnerable populace in rural areas and help improve the movement of people, goods, and ideas within and between hastily developing megacities across Africa. This can also be enhanced by mobilising collaboration amongst a network of African companies, universities, research centres, and public institutions in order to advance the AI research for development agenda and collective investment in collaborative innovation and research that is prioritising solution areas for sustainable development in Africa. These partnerships could mean when Africans design and deploy AI applications, societal goals and human rights commitments like decent work conditions and gender equality are integrated into projects from the beginning.

Introduction

The Global leadership race in AI has commenced in earnest. Various nations have been releasing AI strategies or declarations and making investments, to harness the power of AI for their socio-economic development. Currently, these are dominantly nations of North America, Europe, Nordic-Baltic, South Pacific (Australia, New Zealand), Arabian (UAE), Latin American (Mexico) and Russia, as well as some Asian nations including China, India, Singapore, South Korea, Taiwan, and Malaysia. Also included are two African countries, one sub-Saharan (Kenya), and one North African (Tunisia). An analysis of these strategies by Tim Dutton (2018) showed some elements of uniqueness, with no two strategies being alike, and each focusing on different aspects of AI policy issues. For instance, Canada's AI strategy is distinct from other strategies because it is primarily a research and talent development strategy. While Africa can take a cue from these AI strategy formulation initiatives, there is the imperative to approach the quest to harness AI for its development, with the mind of providing African solutions to African problems.

1.1 Alandthe African Union

In a speech, by the then President Kwame Nkrumah, at the foundation summit of the Organization of African Unity (OAU), in Addis Ababa, Ethiopia, on the 24th of May 1963, he is quoted to have said: “We shall accumulate machinery and establish steelworks, iron foundries and factories; we shall link the various states of our continent with communications; we shall astound the world with our hydroelectric power; we shall drain marshes and swamps, clear infested areas, feed the undernourished, and rid our people of parasites and diseases. It is within the possibility of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial developments.”

Decades since that speech in 1960, the African Union (then OAU) has pursued science and technology as a development priority. In 1980, the Lagos Plan of Action was formulated where there was a formal expression of the awareness of the key role of Science, Technology, and Innovation (STI) in Africa's development. The plan of action recommended the allocation of 1% GDP by Africa's Member States towards STI budget. At the first congress of scientists in Africa on the 30th of June 1987, the Pan-African Union for Science and Technology (PUST) was set up with its headquarters in Brazzaville, Congo and the 30th of June was declared each year as the STI Renaissance day in Africa. Subsequently, the AU Science, Technology, and Innovation Strategy for Africa 2024 (STISA-2024) was developed in a joint collaboration between the African Union Commission (AUC) and the then New Partnership for Africa's Development (NEPAD), as an Expression of Agenda 2063 and a new determination of the African Union in 2014. This is indicated in Figure 1 below. The strategy positioned science, technology, and innovation at the epicentre of Africa's socio- economic development and growth. Its mission was to “Accelerate Africa's transition to an innovation-led, knowledge-based economy.”

In the exploration of technologies worth harnessing in Africa, digital technologies are being touted as a potential solution, in particular AI, which is the bedrock of the 4th Industrial Revolution (4IR). Evidence abounds on the specific realisation of AI application potentials for social transformation and economic development in the advanced economies, and the AI role in the emerging transformative digital revolution in Africa. The role of AI in achieving the SDGs is well articulated in the literature (Vinuesa et al, 2020; Goralski & Tan, 2020). In this regard, the case for AI as an essential part of Africa's development is

not far to seek. This is better articulated by linking in specific terms, AI potentials and relevant Use Cases with the developmental aspirations of the African Union, as espoused in the AU's Agenda 2063, themed as the "Africa we want", (AU 2063), and the STISA-2024 priority areas. A further reflection on AI and Africa's frameworks are discussed in Chapter 1.



Figure 1: The Role of STI in Achieving the Vision of the African Union

1.2 Current Challenges on the Continent

1.2.1 Health

Numerous healthcare systems in Africa are characterised by manual systems with no follow up of ancestral lineages in most of the public health facilities. This is attributed to the low adoption of digital health despite the presence of e-governance policies. Most of the traditional research tools used in Africa are fast becoming inadequate to assist data scientists and researchers in keeping abreast with any global health challenges. Furthermore, health systems in Africa face several structural and operational challenges such as shortages of qualified healthcare professionals and supplies. This results in divergent outcomes for patients. In addition to accessibility barriers between rural and urban areas, thus causing health facility accessibility disparities, the lack of awareness on health issues can be a barrier to seeking care, receiving more effective treatments, and effecting better public health policies.

1.2.2 Agriculture

Agriculture is very critical to Africa's socio-economic growth since the agricultural sector employs over 65% of the continent's labour force. This sector also counts for 32% of the GDP. However, the sector faces numerous challenges such as the degradation of land, increased dependence on inorganic fertilisers, weak supply chain, limited market for the produce, emerging pests and diseases, and climate change. However, despite the potential of AI improving agriculture in Africa, it is still unavailable

outside governmental and research bodies. This is due to the high acquisition costs for the equipment such as drones and automating field tasks. Furthermore, agriculture is a \$3 trillion industry that employs over 1.5 billion people globally. Hence, there are predictions that up to millions of field workers may become unemployed in the next few decades.

1.2.3 Education

Many of the education systems in Africa do produce graduates who are ready for the job market. However, there are concerns that youth in Africa are unable to join the global IT industry. This is because the youth lack access to the appropriate education, they need to advance their careers. They can only access these IT skills that they need only when they travel to Europe, China, Canada, and the USA, before returning to Africa and attempt new businesses in the IT field.

1.2.4 Energy

Africa's energy systems face enormous challenges because of limited capacity in electricity generation and experience. Africa offers the most acute forms of energy poverty in the world. It is estimated that over 630 million people across Africa live without reliable access to electricity and affordable modern cooking fuels. Consequently, solar energy has gained increased usage across African countries. However, most of these systems are not fully exploited to full life cycle due to their poor maintenance.

The Artificial Intelligence Technology

2.1 Definition of Artificial Intelligence

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions. The term may also be applied to any machine that exhibits traits associated with a human mind such as learning and problem-solving¹. It is also known as a field of study which tries to make computers “smart.” These AI computers are meant to work on their own without being encoded with commands. John McCarthy came up with the name “artificial intelligence” in 1955. There are two different types of AI that are known to exist. These are specialised artificial intelligence (weak AI) and artificial general intelligence (strong AI). Specialised AI focuses on performing one or two functions and get better at them over time. On the other hand, artificial general intelligence (AGI) is the hypothetical intelligence of a machine that has the capacity to understand or learn any intellectual task that a human being can. Thus, AGI is a primary goal of some artificial intelligence research and a common topic in science fiction and future studies.

AI is a discipline that is just over 60 years old. It has evolved in the past 20 years from being a mature field of research with a potential for real-world impact to one whose time has come. Currently, the question is not whether AI technologies will have an impact, but rather which sub-areas of AI will develop the next important set of AI technologies, and in which application areas will it have the most significant impact. The purpose of this section is to provide a brief overview of AI as a discipline and to explore its benefits and potential pitfalls. Perhaps surprisingly, there is no universally agreed-upon definition of what AI is. In part, this stems from our perception of intelligence in artificial contexts being situationally dependent and changing as the technology advances. Thus, AI is often a victim of its own success. Once AI technology gains traction, it ceases to be an exemplar of AI. For example, while a calculator was at some point viewed as an instance of AI, this is no longer the case. Broadly speaking, AI can be viewed as a form of data analysis in which conclusions are reached in a sophisticated way and then acted upon.

One of the more useful definitions is the one that was provided by Nils Nilsson, which was: “AI is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment.” However, this definition leaves a substantial scope when it comes to deciding whether a behaviour is intelligent. Furthermore, it is always beneficial to outline what AI is not. Thus, it is always imperative to distinguish AI from Cognitive Science in order to show that AI does not involve the replication of human intelligence, even though, numerous AI technologies have been inspired by human intelligence. It is also important to realise that a crucial component of many AI systems is that it may be required to provide explanations of its behaviour to humans.

AI is a mature, diverse field of research, drawing from disciplines such as Big Data, Computer Science, Data Science, Engineering, Statistics, Mathematics, Applied Mathematics, Cognitive Science, and Philosophy. AI encompasses a wide range of techniques and methodologies. However, our goal in this section is not to cover all of AI, but rather to focus on those areas that have had some recent practical real-world successes, and those that are most likely to lead to major advances in the near future. Thus, it is important to note that focusing exclusively on the current trending topics is a dangerous strategy, and that AI

¹ (Jake Fankenfield, reviewed by Gordon Scott, updated 13 March 2020) <https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp>

should be appreciated for what it is, which is a mature field of study that should be explored in a broader context. One of the main reasons for taking this view is that AI techniques can be combined to achieve more complex intelligent capabilities. Notably, the doomsday scenarios of AI posing a grave and imminent danger to the future of humankind are fictional. However, AI technologies are already influencing our lives and will continue to do so in future. Across the world, AI technologies are extending and enhancing people's well-being in their homes, schools, and clinics. Like most other technologies, AI technologies also have the potential to be abused. Thus, it is up to us as a society, governments, and industry to ensure that policies are put in place to ensure that AI technologies are utilised in a responsible manner. In this regard, appropriate policies are needed urgently because, much as the technological singularity in AI may be decades or centuries away, breakthroughs in technologies are notoriously hard to predict.

Unemployment and inequality are the greatest dangers posed by AI roll-out globally and Africa in the short-to-medium term, possibly contributing to massive unemployment. The anxiety is that AI tools and AI-based artefacts may completely replace human activities in some sectors of the economy. However, this line of thinking fails to appreciate the possibility of the potential and massive benefits of AI technologies to the rest of the African population. This means that AI cannot be restricted to a select and privileged few, and thus further contributing to levels of inequality that are already unacceptably high worldwide. But it is possible to circumvent such undesirable consequences of AI developments. Even though presently, AI technologies seem to be replacing specific human tasks, rather than job categories, if correctly dealt with, the implementation of AI technologies can lead to tremendous economic growth. In fact, AI can contribute to economic throughput and ascertain that all Africans can share the benefits of AI. For these positive outcomes to occur, robust and effective public policies related to AI need to be adopted and enacted urgently.

2.2 Overview of different types of AI

The different kinds of AI include Reactive Machines, Limited Memory, Theory of Mind and Self Awareness. The first two types are known as specialised AI (weak AI) and the last two are known as artificial general intelligence (strong AI). Reactive Machines are the most basic type of AI systems. This type is purely reactive and does not have the ability either to form new memories or utilise past experiences in order to inform current decisions. An example includes an IBM's chess-playing supercomputer known as Deep Blue. This system beat the international grandmaster Garry Kasparov in the late 1990s in chess. Deep Blue can identify the pieces on a chessboard and predict the next moves for itself and its opponent. Moreover, it can select the most optimal realignments from among the possibilities. However, it does not have any concept of the past, nor any memory of what has already occurred.

The other kind of AI is known as Limited Memory. This Type II class contains machines that can consider the past to learn from. For example, self-driving vehicles can observe other vehicles' speed and direction to determine their own. This function cannot be done in a single moment, but rather, it requires identifying specific objects and monitoring them over time. Hence, these observations are added to the self-driving vehicles' pre-programmed representations of the world. This representation of the world also includes lane markings, traffic lights and other important elements, such as the curves in the road. These features and considerations are included when the vehicle decides when and how to change lanes, avoid cutting off another driver and being hit by a nearby vehicle. However, these simple pieces of information about the past are only transient. This means that they are not saved as part of the vehicle's library of experience that it can learn from. This is different from the way human drivers compile experience over years behind the wheel.

The Theory of Mind is a Type III AI that is among the machines that will be built in the future. It falls under the AI machines known as AGIs. This type of machines is more advanced. Not only does it form representations about the world, but also about other agents or entities in the world. In psychology, this function is known as the "theory of mind." The "theory of mind" is an understanding that people, creatures, and objects in the world can have thoughts and emotions that affect their own behaviour. Without the understanding of each other's motives and intentions, and without considering what somebody else

knows either about themselves or the environment, working together is at best difficult, and at worst impossible. Thus, if AI systems are indeed ever to walk among us, they will have to be able to understand that each of us has thoughts and feelings. We also have expectations on how we are treated. Thus, these machines will have to adjust their behaviour accordingly.

Self-aware machines are the final step towards AI development. These are systems that have been built such that they can form representations about themselves. Ultimately, AI researchers will not only understand consciousness but build machines that have consciousness. This is, in a sense, an extension of the “theory of mind” possessed by type III AI machines. Consciousness is also called “self-awareness” because conscious beings are aware of themselves, know about their internal states, and can predict feelings of others. Human beings can assume that someone honking behind them in traffic is angry or impatient because that is how they also feel when honking at others. Therefore, without a theory of mind, humans and future machines cannot be able to make such kind of inferences. Even though, this kind of self-aware machines is probably far from being created AI inventors and researchers should focus their efforts toward understanding memory, learning and the ability to base decisions on past experiences. This is an important step into understanding human intelligence on its own. This will be a crucial aspect towards designing and evolution of AI machines that are more than exceptional at classifying information presented to them.



2.3 Artificial General Intelligence (strong AI)

2.3.1 Tests for Determining Intelligence in AI Machines

There are tests that can be considered to confirm human-level AGI. The first one is known as the Turing test. In this kind of test, a machine and a human both converse with a second human that cannot be seen. The second person must then evaluate which of the two is the machine. Passing the test involves convincing the evaluator in a significant fraction of the time. Notably, Turing does not prescribe what constitutes and qualifies as intelligence. However, the determination that the object is a machine, does disqualify it. The second test is known as the Coffee Test. In this test, a machine is required to enter an average home and figure out how to prepare coffee. This involves finding the coffee machine and coffee, adding water, finding a mug, and brewing the coffee by pushing the proper buttons. On the other hand, the Robot College Student Test involves a machine enrolling in a university, taking and passing the same classes that humans would, and obtain a degree. The Employment Test involves a machine that works in an economically important job and performing at least as well as humans in the same job.

As of 2017, over 40 organisations were actively researching AGI. Various criteria for intelligence have been proposed. The most famous criterion is known as the Turing test. However, to date, there is no definition that satisfies everyone. Nevertheless, here is a widespread agreement among AI researchers that intelligence is required to reason, strategise, solve puzzles, and make judgments under uncertainty. Intelligence also has to represent knowledge, including common-sense knowledge and be able to plan, learn and communicate in natural language. Furthermore, an intelligent being should be able to integrate all these skills towards common goals (Baum et. al., 2017). Other important capabilities include the ability to sense the environment such as seeing and the ability to act such as moving and manipulating objects in the world where intelligent behaviour is to be observed. This would include the ability to detect and respond to hazardous situations. Numerous interdisciplinary approaches to intelligence such as in cognitive science, computational intelligence and decision making tend to emphasise the need to consider additional traits such as imagination, which is the ability to form mental images and concepts that were not programmed in and are autonomous. Computer-based systems such as computational creativity, decision support system, automated reasoning, robot, evolutionary computation, and intelligent agent exhibit most of these capabilities, but not yet at human levels (Grace Et. al., 2018).

2.3.2 Early Estimates of Processing Power Needed to Emulate the Human Brain

For low-level brain simulation, an extremely formidable computer would be required. The human brain has numerous synapses. Each of 10^{11} (100 billion) neurons has on average 7,000 synaptic connections (synapses) to other neurons. It has been estimated that the brain of a 3-year-old child has about 10^{15} synapses, equivalent to 1 quadrillion. But this number declines with age and stabilising by adulthood. Estimates vary for an adult, ranging between 10^{14} and 5×10^{14} synapses, equivalent between 100 and 500 trillion. An estimate of the brain's processing power, based on a simple switch model for neuron activity, is around 10^{14} , equivalent to 100 trillion, synaptic updates per second (SUPS). In 1997, Kurzweil investigated various estimation for the hardware required to match the human brain activity. He suggested that an appropriate figure could be 10^{16} computations per second (cps). For comparison purposes, if a "computation" was equivalent to one "floating-point operation," a measure used to rate the current supercomputers, then 10^{16} "computations" would be equivalent to 10 petaFLOPS. This was achieved in 2011. He used this figure to predict that the necessary hardware would be available sometime between 2015 and 2025 if the exponential growth in computer power at the time of writing continued. Figure 2 shows that the fastest supercomputer from the TOP500 (500 most powerful non-distributed computer systems in the world) mapped by year. Notably, the logarithmic scale and exponential trendline, which assumes the computational capacity double every 1.1 years. Kurzweil believed that mind uploading will be possible at neural simulation, while the Sandberg, Bostrom report is less certain about where consciousness arises (Sandberg et. al., 2009; Kurzweil, 2005).

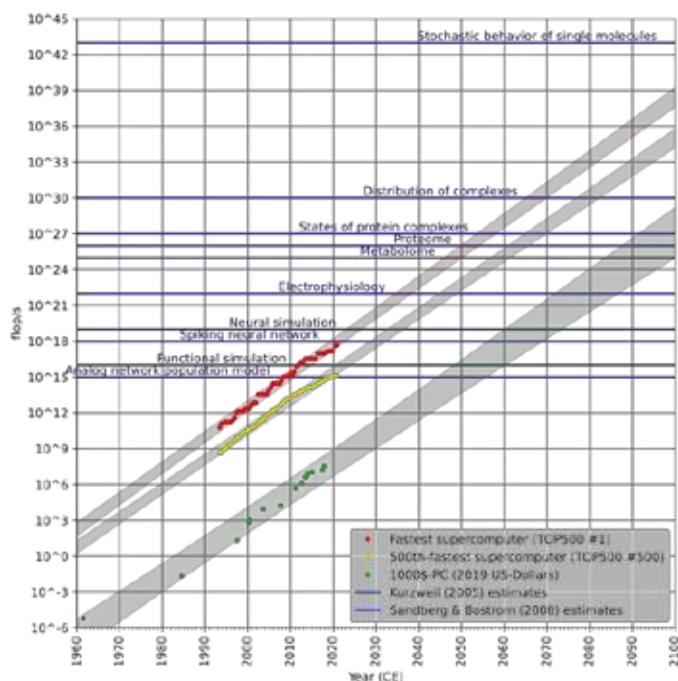


Figure 2: Estimates of how much processing power is needed to emulate a human brain at various levels (Sandberg etc. AI. 2009)

2.3.3 Modelling the Neurons

The artificial neuron model assumed by Kurzweil and used in numerous current artificial neural network implementations is simple compared with biological neurons. A brain simulation would likely have to capture the detailed cellular behaviour of biological neurons, presently understood only in the broadest of outlines. The overhead introduced by full modelling of the biological, chemical, and physical details of neural behaviour, especially on a molecular scale, would require computational powers several orders of magnitude larger than Kurzweil's estimate. In addition, the estimates do not account for the glial cells, which are at least as numerous as neurons, and may outnumber neurons by as much as 10:1. These are also now known to play a significant role in cognitive processes.

Some current research projects are investigating the brain simulation using more sophisticated neural models, implemented on conventional computing architectures. The AI system project implemented non-real-time simulations of a “brain,” with 10^{11} neurons in 2005. It took 50 days on a cluster of 27 processors to simulate 1 second of a model. The Blue Brain project used one of the fastest supercomputer architectures in the world, in IBM’s Blue Gene platform, to create a real-time simulation of a single rat neocortical column, in 2006. This system consisted of approximately 10,000 neurons and 108 synapses. However, a longer-term goal is to build a detailed, functional simulation of the physiological processes in the human brain. But, Henry Markram, the Director of the Blue Brain Project, in a 2009 TED (Technology, Entertainment, Design) conference in Oxford, stated that it is possible to build a human brain, and this could be done in 10 years. There have also been controversial claims to have simulated a cat brain. Neuro-silicon interfaces have been proposed as an alternative implementation strategy that may scale better. In addressing the argument that brains are more complicated and neurons have to be modelled in more detail. Hans Moravec in his 1997 paper, known as “When will computer hardware match the human brain?” measured the ability of existing software in order to simulate the functionality of neural tissue, specifically the retina. His results showed that the activity did not depend on the number of glial cells, nor the kind of processing neurons where the activities were being performed (Sandberg et. al., 2009).

2.3.4 Criticisms of Simulation-Based Approaches

A fundamental criticism of the simulated brain approach derives from embodied cognition where human embodiment is taken as an essential aspect of human intelligence. Numerous researchers believe that embodiment is necessary to ground meaning. If this view is correct, any fully functional brain model will need to encompass more than just the neurons; i.e., a robotic body. Goertzel proposed virtual embodiment, such as the Second Life, but it is not yet known whether this would be sufficient. Moreover, it is known that desktop computers using microprocessors capable of more than 1^{10^9} cps have been available since 2005. According to the brainpower estimates used by Kurzweil and Moravec, this computer should be capable of supporting a simulation of a bee brain. However, despite some interest, no such simulation exists. The reasons for this phenomenon include the fact that the neuron model seemed oversimplified. Furthermore, there is insufficient understanding of higher cognitive processes to accurately establish what the brain's neural activity, observed using techniques such as functional magnetic resonance imaging, correlates with. Additionally, even if our understanding of cognition advances sufficiently, early simulation programmes are likely to be extremely inefficient and will. Therefore, this needs considerably more hardware. Lastly, the brain of an organism, while critical, may not be an appropriate boundary for a cognitive model. To simulate a bee brain, it may be necessary to simulate the body and the environment. The Extended Mind thesis formalised the philosophical concept, and research into cephalopods has demonstrated clear examples of a decentralised system. In addition, the scale of the human brain is not currently well-constrained. One researcher estimated that the human brain is about 100 billion neurons and 100 trillion synapses. Other researchers also estimated that the human brain is 86 billion neurons, of which 16.3 billion consists of the cerebral cortex and 69 billion is the cerebellum. Glial cell synapses are currently unquantified but are known to be extremely numerous.

2.3.5 Strong AI and Consciousness

In 1980, a philosopher known as John Searle coined the term “strong AI” as part of his Chinese room argument. He wanted to distinguish between two different hypotheses about artificial intelligence. The first hypothesis was that an artificial intelligence system can think and have a mind. The other hypothesis was that an artificial intelligence system can only act like it thinks and has a mind. The first one is called “the strong AI hypothesis” and the second is “the weak AI hypothesis.” This is because the first one makes the stronger statement since it assumes something special has happened to the machine that goes beyond all its abilities that we can test. Searle referred to the “strong AI hypothesis” as “strong AI.” This usage is also common in academic AI research and textbooks. On the other hand, the weak AI hypothesis is equivalent to the hypothesis that artificial general intelligence is possible. According to Russell and Norvig, “most AI researchers take the weak AI hypothesis for granted, and do not care about the strong AI hypothesis.” In contrast to Searle, Ray Kurzweil uses the term “strong AI” to describe any AI system that acts like it has a mind, regardless of whether a philosopher would be able to determine if it actually has a mind or not. In science fiction, AGI is associated with traits such as consciousness, sentience, sapience, and self-awareness observed in living beings. However, according to Searle, it is an open question of whether general intelligence is sufficient for consciousness. “Strong AI,” as defined above by Kurzweil, should not be confused with Searle’s “strong AI hypothesis.” The strong AI hypothesis is the claim that a computer which behaves as intelligently as a human being must also necessarily have a mind and consciousness. However, AGI refers only to the amount of intelligence that the machine displays, with or without a mind.

2.3.6 Controversies and Dangers of AGI

2.3.6.1 Feasibility

As of March 2020, AGI remains a speculative technology. As such, there are no AGI systems that have demonstrated functionality. Presently, opinions vary on whether and when artificial general intelligence will arrive, and if it may arrive at all. At one extreme, AI pioneer Herbet A. Simon speculated in 1965 that machines will be capable, within 20 years of doing any work a man can do. However, this prediction failed to come true. On the other hand, Microsoft co-founder Paul Allen believed that

such intelligence is unlikely in the 21st century because it would require unforeseeable and fundamentally unpredictable breakthroughs and a scientifically deep understanding of cognition. Writing in *The Guardian*, roboticist Alan Winfield claimed the gulf between modern computing and human-level AI is as wide as the gulf between current space flight and practical faster-than-light spaceflight. Additionally, AI experts' views on the feasibility of AGI wax and wane and may have seen a resurgence in the 2010s. Four polls conducted in 2012 and 2013 suggested that the median guess among experts for when they would be 50% confident AGI would arrive was between 2040 and 2050, with the mean being 2081. Of the experts, 16.5% answered with "never" when asked the same question. However, 90% of the experts had confidence in the success of the technology in future (Boucher, 2019).

2.3.6.2 Potential threat to human existence

The thesis that AI poses an existential risk, and that this risk needs much more attention than it currently gets, has been endorsed by many public figures. Perhaps the most famous are Elon Musk, Bill Gates, and Stephen Hawking. The most notable AI researcher to endorse the thesis is Stuart J. Russel. Endorsers of the thesis sometimes express bafflement at sceptics. For example, Bill Gates stated that he does not understand why some people are not concerned about AGI's potential threats to humanity. Stephen Hawking criticised widespread indifference in his 2014 editorial and said:

"So, facing possible futures of incalculable benefits and risks, the experts are surely doing everything possible to ensure the best outcome, right? Wrong. If a superior alien civilisation sent us a message saying, 'We'll arrive in a few decades,' would we just reply, 'OK, call us when you get here—we'll leave the lights on?' Probably not—but this is more or less what is happening with

Numerous scholars who are concerned about existential risk believe that the best way forward would be to conduct extensive research into solving the difficult control problem. This will therefore answer the question of what types of safeguards, algorithms, and architectures can programmers be able to implement in order to maximise the probability that their recursively improving AI would continue to behave in a friendly, rather than destructive, manner after it reaches superintelligence. On the other hand, the thesis that AI can pose existential risk also has countless strong detractors. Sceptics sometimes charge that the thesis is crypto-religious, with an irrational belief in the possibility of superintelligence replacing an irrational belief in an omnipotent God. At an extreme, Jaron Lanier argued that the whole concept that current machines are in any way intelligent is an illusion and a stupendous con by the wealthy (Hamblin, 2014). However, much of the existing criticism argues that AGI is unlikely to be realised in the short term. Computer scientist such as Gordon Bell argued that the human race will already destroy itself before it reaches the technological singularity. Gordon Moore, the original proponent of the Moore's Law, declared that: "I am a sceptic. I do not believe that a technological singularity is likely to happen, at least for a long time. And I do not know why I feel that way." Andrew Ng, the Vice President of Baidu stated that AI existential risk is "like worrying about overpopulation on Mars when we have not even set foot on the planet as yet."

2.4 Specialised Artificial Intelligence (Weak AI)

The transport sector is one of the major beneficiaries of the weak AI where a significant contribution has been made. As with other application areas of AI, the primary reason for the existing widespread adoption of AI in transportation is the scale and diversity of individual and population-level transportation data. Therefore, this has made possible innovation on a variety of AI applications related to transport, such as real-time prediction and route navigation. For example, GPS devices were first introduced into vehicles in the early 2000s and are fast becoming a fundamental part of transportation infrastructure. The same goes for other devices with sensing capabilities such as accelerometers and moisture sensors. Moreover, autonomous transportation, whether it be in the form of autonomous public transport, self-driving cars, or self-driving trucks, is likely to become the norm in the near future.

Business Process Automation using Smart Devices and Robotics is another application area with great potential in AI. While automation in various forms has been used in numerous industries for years, it is only in the past ±15 years that physical robots and smart appliances have started to enter people's homes and businesses. This is due, in large part, to a positive feedback loop where AI advances are inspired by mechanical innovations which, in turn, prompt new AI techniques to be introduced. Furthermore, advances in hardware are making it possible to embed high-performing specialised processors into low-cost devices. Therefore, this means that it will soon be possible to support more sophisticated AI in smart devices than was previously possible. For example, in recent years low cost, safe, robot arms have been introduced to hundreds of research laboratories around the world.

Healthcare is another application area worth considering. As with most of the other application areas that were considered, progress in machine learning, coupled with the possibility of large-scale data collection, is making it possible to diagnostically infer possible health risks automatically. This could potentially provide for an experience where the human dimension of care is augmented with automated reasoning processes. This phenomenon is already happening to some extent and will continue to improve in future. Additionally, driven by the mobile computing revolution it has become possible to combine social and healthcare data. Thereby, opening possibilities for prediction, both on the personal and population level that would otherwise be simply impossible. As in other application areas, the main obstacles for AI technologies to reach their true potential in the area of healthcare are not technological, but rather psychological, sociological, ethical, and legal. These relate not only to the efficacy and accuracy of these methods but, especially in the health domain, to security and privacy concerns. It is crucial that AI systems gain the trust of both healthcare professionals and ordinary people. In this context, improvements in methods for interacting with medical professionals and patients will be a critical challenge.

The final application area for consideration for weak AI is Public Safety and Security, as it is amongst the most controversial AI application component. Like the others, it is an area in which AI tools have already been deployed successfully. In this area, perhaps more than in others, it is imperative to gain public trust. This is because there are legitimate concerns that the incorporation of AI into the maintenance of public safety and security could become too pervasive and invasive. At the same time, it is worth noting that AI could also contribute to reducing the overbearing policing methods by ensuring that such methods are targeted appropriately and used only when needed. For example, machine learning can significantly enhance the ability to predict where and when crimes are most likely to occur and who may be responsible for committing them. Such predictive policing tools could raise the spectre of innocent people being unjustifiably targeted. Thus, well-deployed AI prediction tools have the potential to remove or reduce human bias, rather than reinforcing it. Therefore, it is imperative that research and resources be directed toward ensuring this effect. Similarly, tools already exist that are being used for scanning various social media forums to look for certain types of events and how they may impact security. For example, AI can help in social network analysis to prevent those at risk from being radicalised by violent groups. Hence, law enforcement agencies are increasingly interested in trying to detect plans for disruptive events from social media as well as monitor activities at large gatherings of people in order to analyse security. But the very success of such methods has led to legitimate concerns about the potential for law enforcement agencies to overreach and use such tools to violate people's privacy.

2.5 Addressing the myths and misconceptions about AI technology

AI has sparked excitement and robust discussions among STIs across various platforms. Notably, there have been discussions about the unprecedented potential of AI to possibly revolutionise all aspects of peoples' lives. However, as with anything new, there are certainly myths and fake news surrounding the adoption of AI in our every day's lives. This has raised tremendous concerns among the public that has led to fear and distrust. Thus, this section intends to address some of the basic misconceptions and frequently peddled mistruths.

The first myth about AI is that AI will completely replace all jobs. Certainly, it has been predicted that the advent of AI and automation will potentially disrupt the labour force. In some situations, it is already disrupting numerous industries across the globe. However, it is misleading and an over-simplification to consider this transition as a straightforward transfer of labour from humans to machines. Based on historical observations, previous industrial revolutions have undeniably resulted in the transformation of the employment landscape. For example, during the 19th century, there was a mass shift from agricultural work to factories among numerous economies across the world. In the 20th century, the introduction of computers and the internet led to a robust increase in jobs. The number of jobs created because of these transformations was adjusted for the rapid growth in population that had principally remained consistent. Moreover, despite what doom-mongers have proclaimed with regards to job losses, there has been very limited actual evidence that suggests the likelihood of massive unemployment due to widespread redundancy of human workforces. In contrast, there have been strong forecasts of possible better productive economic activities that will be afforded by the increased efficiency and reduction of waste that automation promises. Consequently, this will provide the workforce with more options for better spending their time on productive and income-generating pursuits. In the short-term, employers are generally looking at AI technology as a method of augmenting human workforces and enabling them to work in newer and smarter ways.

The second myth is that only low-skilled and manual workers will be replaced by AI and automation. This is a misconception because AI-based robots and machinery are generally reserved for sophisticated tasks in manufacturing, mining, healthcare, banking, and public services. This is aimed at reducing the drudgery of the day-to-day aspects of the work. For example, in the legal field, AI can be utilised in hastily analysing numeral documents so to extract relevant information for ongoing cases. In healthcare, machine learning algorithms can analyse and evaluate scans of X-rays for diagnostic purposes on early warning signs of diseases, as they are proving to be highly competent at detection. However, most of these AI technologies and machines will require the intervention of the human touch procedures in their operations. For example, a lawyer would still have to present arguments in court in front of a judge. In medicine, the healthcare practitioners will still need to consult with their patients about the diagnosis and discuss the future care protocols in the most considerate and helpful way. These aspects of the jobs are less likely to be automated, but members of their respective professions could find that they have more time for their jobs. This is because the mundane drudgery is routinely automated and tedious aspects of their jobs had been eliminated. Therefore, the practitioners may become more competent at their jobs.

There is another perception that super-intelligent computers will develop to a level where they become superior to humans at performing tasks. Broadly speaking, there two groups of AI applications known as specialised and generalised AI. Specialised AI involves technologies that are focused on performing one job, or working in one field, and becoming increasingly good at it. The legal and medical applications are typical examples of such technology. On the other hand, generalised AI are technologies that are capable of applying themselves to several different tasks, just as human or natural intelligence can. However, this kind of advancement is still somewhat further off to being realised. Thus, it is more likely that it will take some time before this kind of generalised AI-inspired robots come face-to-face with humans. This implies that it will take some time before artificial intelligence quickly overtakes and outpace human intelligence. This misconception is brought about by imagining that intelligence is manifested in a linear scale. This is perpetuated by the fact that humans always imagine that perhaps animal's score at the lower end of the scale, humans are at the higher end, and with super-smart machines at the top of the scale. However, in reality, intelligence is appraised in several dimensions. For example, when regarding the speed of calculations and capacity for recall, computers can far outpace humans. But the super-smart machines do not possess the creative ability, emotional intelligence such as empathy and strategic thinking, which are qualities that only humans can offer, at least in the foreseeable future.

2.6 Recent Advances in AI

An analysis of the history of computing technologies shows that technological changes are usually exponential. This is in line with Ray Kurzweil's "Law of Accelerating Returns" (Kurzweil, 2000). This means that, as time passes, technology changes faster. This phenomenon has also been observable in the advances in AI technologies. Therefore, this demands that both the current technology landscape, as well as its ebbs and flows, be clearly understood. Consequently, Africa's ability to realise the future of the AI technologies will depend on her own developmental goals' context that requires a mastery of the change. AI technologies are causing changes to the technology landscape by creating new segments such as self-driving cars, destroying existing segments such as GPS trackers, and transforming other technological segments such as automobiles. Thus, for Africa to greatly harness AI for its socio-economics' progress, the prerequisite is to classify, exploit, and outline emerging AI technologies according to Africa's framework. Therefore, African needs to either embrace or overlook some aspect of AI as the deviations in the landscape continue to unfold. In this way, Africa must invest, utilise, and influence the AI technology implementation for cost-effectiveness, framework assessment, thus Africa's socio-economic development.

Overwhelming evidence is showing that AI is a disruptive and transformative set of technologies, and Africa is on the cusp of such an AI revolution. AI, as a discipline of just over 60 years old, during the first 40 years of its development, some of the important AI successes were limited to research laboratories. However, during the last 20 years, the substantial changes and developments of sophisticated intelligent systems were adopted by governments and numerous industries, worldwide. The factors that have significantly contributed to this dramatic shift included the developments in the fields of Computer Vision, Natural Language Processing (NLP) and Knowledge Representation and Reasoning (KR). NLP is a mixture of artificial intelligence and computational linguistics. This means NLP is the machine's ability to process information (what is being said), structure the information received, determine the necessary response, and respond in a language that humans can understand. The most popular applications of NLP include machine translation, speech recognition, sentiment analysis, question, answering (concerned with building systems that automatically answer questions posed by humans in a natural language), automatic summarisation, and chatbots (several channels, including the internet, applications, and messaging platforms). Another application of NLP is market intelligence, where marketers use NLP to search for people with a likely or explicit intention of making a purchase. In this case, people's behaviour on the internet, maintaining pages on social networks and queries to search engines provide a lot of useful unstructured customer data. Selling the right advertisement for internet users allows Google and Facebook to make the most of its revenue. In this case, advertisers pay Google every time a visitor clicks on an advertisement. A click can cost anywhere between a few cents and more than \$50. Moreover, NLP can be used in text classification. Text classification is the task of assigning a set of predefined categories to free text. Text classifiers can be used to organise, structure, and categorise almost anything.

Machine learning, as sub-area of AI, has enhanced learning and predictive algorithms as well as the progress in relevant hardware technology. Consequently, this has led to the availability of unbelievably hefty amounts of data that were mostly harvested from huge online repository companies such as Google, Facebook, and Amazon. Notably, the advances in Machine Learning have significantly benefitted other sub-areas of AI such as computer vision, speech recognition, affective computing, and natural language processing. These benefits have also cascaded to automated decision making. Machine learning focuses on using statistical techniques to build intelligent computer systems in order to learn from databases available to it. Currently, Machine Learning has been used in multiple fields and industries such as medical diagnosis, image processing, prediction, classification, learning association, regression.

Another example of machine learning is speech recognition. Speech recognition is the translation of spoken words into the text, known as computer speech recognition or automatic speech recognition. Here, a software application can recognise the words spoken in an audio clip or file, and then subsequently convert the audio into a text file. The measurement in this application can be a set of numbers that represent the speech signal. The speech signal can be segmented by intensities in different

time-frequency bands. Thus, speech recognition can be used in applications such as voice user interface, and voice searches. Voice user interfaces include voice dialing, call routing, and appliance control. It can also be used as a simple data entry and the preparation of structured documents. In Medical diagnosis, Machine Learning can be used in diagnostic techniques and tools of diseases. It is used for the analysis of the clinical parameters and their combination for the prognosis.

Recent advances in automated decision making are largely attributed to developments in the area of learning to deal with matters of representation and scalability. An excellent example of such advancement is in robotics, where navigation in static familiar environments is essentially a solved problem. Nevertheless, current research is focused on developing capabilities and functionalities of robots into being able to operate under unfamiliar environments through active and continual learning capabilities. The successful advancement of deep learning, which is an advanced and complex form of neural networks, has enhanced all systems of automation, including robotics, and expected to continue this trend into the near future. The traditional model of computing provides for clearly separated modules for input/output, instruction processing, and memory management. Presently, the deep neural networks are simulated on machines built with the standard model of computing in mind. Thus, it is anticipated that so-called neuromorphic computers, machines that have been designed based on biological neural networks and premised on a radically different model of computing, will provide a much better environment in which to train and execute deep neural networks, possibly leading to even bigger gains in the application of Deep Learning. For example, researchers have been able to restore an injured man's sense of touch by using Brain-Computer Interface Technology in USA (Battelle and Ohio State University Wexner Medical Centre).

In line with the social aspect of AI discussed above, is the premise that a wide array of devices, including appliances, vehicles, and buildings, can be interconnected to collect and share their sensory information in sophisticated and intelligent ways, leading to the so-called Internet of Things (IoT). It is expected that AI can process and use the resulting huge amounts of data. The advantage of AI in the IoT is the fact that AI could help streamline and make sense of the bewildering array of incompatible communication protocols these devices employ presently. An inevitable consequence of the myriads of such devices becoming linked to online systems is that the whole industry will be in possession of large datasets which can be analysed for different purposes and exploited for good or otherwise.



2.7 Conclusion

Leading countries in AI, have shown that creating enabling environments, for increasing cooperation and exchange of information between diverse stakeholders: academia; industry (including start-ups and entrepreneurs), civil society (including NGOs and think tanks); policymakers and regulators will accelerate advancement in AI applications. Multi-sectoral collaboration is essential for the safe, ethical, and beneficial development and the utilisation of AI technologies. Thus, Africa should not be left behind in active participation, posting African perspective, in the ITU-facilitated series of AI for Good Global Summit. The Good Global Summit brings together governments, industry, academia, and civil society, to explore the responsible development of human-centric AI in solving humanity's grand challenges, including accelerating the SDGs. Specific recommendations on this aspect are provided in the latter part of this booklet. Furthermore, numerous countries and economic unions have shown that it is critical to enact policy and regulatory framework that promotes AI harnessing and encourages innovation and investment to successfully implement AI application endeavours. Currently, AU should encourage African governments to pursue a deliberate and proactive approach, to implement supportive regulation, policies, and initiatives. Lastly, there are several areas relevant to the development of AI-enabled robust digital economies, where policymakers should focus. This is elaborated upon in the latter part of this report.

In this section, a range of application domains in which AI technologies have already had an impact, and where AI technologies are likely to have an impact in the next few decades are considered. With the increasing interest for numerous African governments in implementing AI for their countries, it is also appropriate to look for opportunities that exist and challenges that these countries will face when incorporating AI into their systems. This is because numerous people have been confused about whether to start AI-based development because of the dilemma of how AI will impact on socio-economic development and growth. The reason for this uncertainty lies in the strong perception that AI will disrupt every aspect of people's lives, hence, AI appears to emanate enthusiasm and scepticism simultaneously for numerous communities across the globe.

AI Applications and Opportunities

3.1 Current and possible future applications of AI

The applications for artificial intelligence are endless. The technology can be applied to numerous sectors and industries. AI-enabled systems as at now are being adapted and incorporated into different applications across healthcare, agriculture, mining, industry, and government public service enterprises, as they get more sophisticated (Abney, 2013). AI is being tested and used in the healthcare industry for dosing drugs and different treatment in patients, and for surgical procedures in the operating room. Worth noting is that AI is still growing traction as a maturing technology, and current AI systems still possess quite a basic capacity to recognise the human expression, tone, emotion, and subtleties of human interaction. Progress has been made attempting to teach computers to accomplish limited actions such as playing a game, recognising an image, and predicting traffic flow/congestions. More innovative work remains to be developed before AI-based technologies that can perform human tasks are realised. However, it is encouraging that Africa and the rest of the globe are currently undergoing an unparalleled period of technological innovation.

Perhaps, the most important factor relates to the recent advances made in the sub-area of AI known as machine learning. These advances have been realised by developments in learning and predictive algorithms (such as regression and trend analysis based on statistics, and artificial neural networks, which are computational models and can mimic the human brain), progress in hardware technology, and the availability of incredibly large amounts of data, primarily collected on large online repositories by companies such as Google, Facebook, and Amazon. The advances in machine learning have had hugely beneficial effects on other sub-areas of AI, most particularly computer vision, speech recognition and natural language processing. It has also had a beneficial effect on automated decision making. Recent advances in automated decision making can largely be attributed to developments in the area of machine learning in order to deal with matters of representation and scalability. A typical example of such a phenomenon is robotics, where navigation in static familiar environments is essentially a solved problem. But current research is largely focused on the development of ways and methods that can enable robotics operations in unfamiliar environments. This is where machine learning plays a crucial part.

3.2 Opportunities

Although the focus in AI is on the automation of intelligent behaviour, there is a clear recognition that intelligence frequently involves the cooperation of some kind between stakeholders. This cooperation can be forged with human beings and/or other intelligent systems. Presently, there is strong interest in the development of such Collaborative Systems. The focus is primarily on the development of formal models of collaboration and capabilities needed by Collaborative Systems to become effective partners. The advantage of, and indeed the necessity for, instilling collaborative capabilities into AI systems should be obvious. A typical example of such an advantage is in the application domain of self-driving vehicles. For instance, such companies include Google and Tesla that have already demonstrated the feasibility of this technology with respect to driverless motor vehicles. Nonetheless, for these systems to be scalable to a sophisticated level of collaboration within, as well as between, self-driving vehicles and humans, will prove to be crucial. In a similar vein, the area of Crowdsourcing and Human Computation is premised on the assumption that human abilities in some areas will, for the foreseeable future, be superior to that of automated methods. Additionally, Crowdsourcing and Human Computation are premised on the fact that the greatest solutions will be obtained by harnessing a combination of the abilities of human beings and AI machines. The best example of such a system is known as Wikipedia. Wikipedia is a knowledge repository that far exceeds more traditional information sources in terms of both scale and depth.

3.3 Current uses of AI in Africa

3.3.1 Agriculture

Agriculture is one of the sectors in Africa that has observed tremendous contributing to AI-based technologies. AI techniques are used to solve various problems in agriculture, including:

- Weather prediction;
- Soil monitoring, for example, soil fertility, over-fertilisation;
- Automated irrigation;
- New farming techniques with smart greenhouses;
- Crop monitoring, for example, determining sowing depth, sowing date;
- Harvesting. For example, CROO robotics for picking strawberries; and
- Pests, diseases, and weeds prediction. For example, detecting grasshoppers, as well as identifying weeds and deciding when to apply pesticides.

Data is captured using drones and/or embedded systems in farming machinery. Thereafter, AI techniques are implemented to analyse this obtained data to find solutions for the various agricultural problems. In South Africa, there are several AI start-ups that are solving such problems in agriculture. For example, MySmartFarm, Aerobotics, Drone Clouds, and FarmDrive are AI-enabled technologies developed in South Africa in order to address agricultural issues such as plant disease diagnosis, price prediction, marketing, expert consultation, and access to financial services.

3.3.1.1 Case Study: FarmDrive: AI-Enabled Innovation Providing - Alternative Credit Scoring Model for Smallholder Farmers

This case study relates to the Agenda 2063 goal of modernising agricultural activities for improved productivity and production. Undoubtedly, agriculture is cardinal to Africa's future. The continent has most of the world's arable land, with over half of the African population employed in the sector. And also, it is the largest contributor to total gross domestic product (GDP) (AGRA, 2018). However, farmers comprise the largest and poorest group at the bottom of the pyramid. So, financial tools for farmers can have a remarkably high impact potential on their socio-economic development and growth. This is because sustained growth in the agriculture sector has proven to be 2 to 4 times more effective at reducing poverty and improving livelihoods than growth in other sectors (AGRA, 2017). Millions of smallholder farmers in Africa are struggling to support their families and communities through agri-business. This is because less than 10% have their economic needs met by the financial sector. In addition, less than 1% of bank lending in Africa goes to agriculture (AGRA, 2017). In the absence of accurate and cost-effective methods for assessing small-scale agricultural credit risk, financial institutions are reluctant to lend to smallholder farmers. Thus, this shortfall contributes significantly to the \$450 billion global agriculture financing gap across the globe (AGRA, 2018). Consequently, without access to credit, small-to-medium farmers remain unable to purchase quality inputs, make productive investments, and improve their productivity and harvests.

Families and communities face real frustrations in agriculture, and as a result, realise meagre harvest after months of toiling away. Additionally, capital required to purchase the critical farming inputs that could potentially improve their yields and revenues is often deficient. Consequently, start-up companies such as FarmDrive are employing AI-enabled innovative solutions that are aimed at bridging the gap between smallholder farmers and financial institutions. This could result in the unlocking of access to credit for smallholder farmers. FarmDrive utilises mobile cellular phones, alternative data, and AI machine learning techniques, to close the critical data gap that prevents financial institutions from lending to creditworthy smallholder farmers. FarmDrive enables smallholder farmers to have access to loans and financial management tools through a cellular mobile phone application called FarmDrive App. This application enables farmers to register on FarmDrive by SMS to 21342. Once registered,

the application allows farmers to keep records of their farming business activities such as income and expenses. This becomes a trusted source of financial behaviour and standing of farmers which can then be utilised for applying for loans. Farmers can obtain loan approvals and receive the loan via M-PESA (another innovation for financial services). It also allows for farmers timely repayments of the loan. Thus, FarmDrive's alternative AI-based credit risk assessment model provides financial institutions with an agriculturally relevant and data-driven model to assess risk and develop loans that fit the needs of smallholder farmers. Consequently, FarmDrive has the potential to unlock millions of dollars of previously risk-averse capital to smallholder farmers that can potentially improve the livelihoods of communities. Thereby, alleviate poverty, hunger, and inequalities. In relation to the AU 2063, considering that in Africa, sustainable agriculture is the most effective tool to end poverty, the AI-driven FarmDrive innovation is of great relevance. Specifically, FarmDrive has the enabling potential to contribute to:

- Bridging the credit access gap for smallholder farmers, thus enabling them to properly farm, with quality inputs, the fertile land space in African nations, and so, contribute to lifting millions out of poverty.
- Equipping millions of smallholder farmers in Africa to increase their productivity, and therefore contributing to improved food security, towards zero hunger goals.
- Providing alternative credit scoring model that ensures financial inclusion for the disenfranchised women that make up 60% of African smallholder farmers.
- Revitalising agri-business and provide Africa's youth with quality, sustainable economic opportunities, with the introduction of data-driven AI technology solutions for the challenges faced in agriculture.
- Capacitate smallholder farmers to have access to credit, and so can sustainably contribute to economic development while improving their livelihoods and leading to reduced inequalities.



3.3.2 Mining

In Africa, AI has been used in the mining industry to address various issues. For example, in the South African mining industry, a smart-sort-system employed by TOMRA Kumba uses drones to drill holes and drop explosives for excavation. Exxaro's Grootegeluk coal mine uses drones for surveying and mapping in order to increase production through better efficiency in coal

3.3.2.1 Case Study on Mining: Drones for

The use of drones and AI has contributed to automating operations in mines in Africa. For example, Rocketmine is a mining start- up that is based in Johannesburg. This company services mines across the continent including Nigeria, Namibia, and

Ghana. For mapping purposes and excavation for new sources of minerals, periodic mining surveys are imperative to the proper functioning of the mines. Traditionally, these periodic mining surveys have been performed manually, bi-monthly, with aircraft flying over the mines. However, Rocketmine has provided a solution in which the manual surveys are now conducted by drones. These drones are used to capture photographs, which are then analysed by using AI techniques in order to conduct the survey. A similar approach has also been employed in Exxaro's Grootegeuk mine in Limpopo, South Africa. This mining area poses hazardous and dangerous conditions for surveyors. Thus, drone technology becomes an appropriate and cost-effective approach for carrying out surveys in this mining area. Furthermore, with the drone technology coupled with AI, data is provided much more frequently, which is on 12-hourly shifts, instead of twice a month as a result of the manual survey. Additionally, at Rossum Uranium in Namibia, Rocketmine is using drones to identify the location and movement of stockpiles. Moreover, Rocketmine has also emulated mines digitally to enable contractors to manage mines remotely. The Belfast mine in Mpumalanga has also been emulated digitally.

3.3.3 Manufacturing

Since its inception, AI has been playing a critical role in manufacturing. Some of the earlier applications include design and planning of plants and machines, fault diagnoses, such as maintenance of industrial facilities. As the field progressed, AI has provided effective solutions to industrial vehicle routing problems, product packaging problems and scheduling of machines in industries. For example, Opsi systems is a spin-off company from the University of Witwatersrand in South Africa. Opsi systems focus on software development and consulting, specialising in the supply chain, with a specific focus on vehicle logistics and demand prediction. This service is useful for manufacturing companies because they are able to transport their products to clients. Moreover, AI has also been able to provide solutions to problems in cybersecurity such as network intrusion detection, malware detection, fraud detection and anomaly detection. South Africa AI-enabled Data Prophet used for manufacturing industry quality assurance automation.

3.3.3.1 Case Study: Data Prophet for Manufacturing Industry Quality Assurance Automation

Data prophet is a suite of AI system solutions for manufacturing industry automation, generically named, OMNI. OMNI is a predictive AI system for manufacturing. When coupled to production data, OMNI learns from the available data to become an expert advisor with experience in production history, able to guide the production team to eliminate defects and scrap to minimise downtime. Using its AI computer vision tools, named OMNI Vision, it functions as a machine vision system that enhances the effectiveness of human quality control operators. This enables the system to locate and classify defects on components that the system has never seen before. Hence, by learning from historic data, data prophet can build up models to predict where and when these problems may recur, and pre-emptively recommend corrective action, leading to cost savings. OMNI Vision, rather than using template matching to detect manufacturing defects, uses AI machine learning techniques, to provide a comprehensive visual Quality Control solution, for Industry 4.0. OMNI Vision has a proven record of accomplishment in the foundry industry, where it has helped a sizeable green sand-casting foundry, to significantly cut down on common debilitating casting defects.

Notably, since Data Prophet was invented in Africa, this is changing the global landscape of technology transfer flow that places Africa as a net importer of technologies, but as an innovator. For example, the Data Prophet AI-enabled conversational agent for inquiries and emotion detection via the image has been integrated into a game for the major Japanese publisher, Bandai Namco. Also, Data Prophet has contracted with manufacturing giants in Germany and the US to deploy its AI solutions.

For example, in 2018, Data Prophet secured a “multi-million dollar” funding round from venture capital firm, known as Knife Capital, which intended to drive the expansion of its international offerings into the US and Europe.

Data Prophet, as an AI-start-up company, does the following:

- Contributes to sustainable economic growth in the manufacturing sector, thus attracting venture capital into the African economy;
- Focuses on manufacturing quality control and contributes to the advancement of industrialisation, as well as fostering innovation that leverages to the South African GDP; and
- Creates knowledge-based decent employment for its workforce and attracts venture capital inflow for African economic growth.

3.3.4 Health

AI is the most discussed topic in healthcare, not only in Africa but globally. This is, however, sparking ongoing debate about the ethical, clinical, and financial pros and cons of relying on AI algorithms for patient care. Nevertheless, to build such systems, there is a need for reliable data which is not readily available in Africa. There is also a need for robust clinical evaluation, using metrics that are intuitive to clinicians and ideally go beyond measures of technical accuracy to include quality of care and patient outcomes. Additionally, AI-empowered systems can be used in speeding patient information retrieval, processing, triage, diagnoses, and post-care follow up. For example, in Uganda, a start-up, known as Global Auto Systems Ltd has implemented an integrated oncology management system to keep track of cancer patients in several private cancer screening units. This clearly demonstrates that AI systems can be used for reliable, timely and accurate disease diagnosis and detection. This can be achieved by analysing patterns in health and testing data such as machine vision analysis of X-Rays, AI for microscopy slide analysis of pap-smears and malaria slides. For example, a researcher at Mbarara University of Science and Technology (MUST) developed a platform dubbed PapsAI for automated diagnosis and classification of cervical cancer from pap-smears. Furthermore, AI systems can be used to provide information to the public and health care providers. For example, Online Conservation Agents (OCA) can provide expert guidance to the end-user. Moreover, telemedicine applications can be used to remotely diagnose various health conditions using images from cameras of a smartphone.

AI is also playing an important role in the health sector in Africa. For example, in Kenya, AI is being utilised to assist patients and medical facilities in identifying the availability of medical supplies. This has resulted in a 50% increase in medical supply availability. Moreover, AI is also being used for diagnostic prediction and early cure or treatment for health challenges such as cancer, malaria, and birth asphyxia. For instance, in rural clinics in Kenya AI is used to detect cervical cancer. In addition, IBM Research in Kenya is employing AI to prevent the spread of Malaria. Furthermore, in Nigeria, Buena is using AI to detect the possibility of birth asphyxia.

Notably, resistance to medication has also been detected using AI in Africa. For example, The Heal in South Africa has employed AI to predict Human Immunodeficiency Virus (HIV) drug resistance and non-adherence to tuberculosis treatments for infected patients. Additionally, in North Africa, Computer-aided detection (CAD) systems in mobile systems are being used to assist with mammograms examination in order to prevent breast cancer. Moreover, AI has been employed to provide patient support and advice. For example, a company known as Woebot in the US has developed an application with an AI chatbot that can provide a platform for health practitioners to diagnose patients with their medical health complications. In addition, in Nigeria, Aajoh uses AI to provide the public with medical diagnoses upon submission of symptoms in the form of text, images and audio clips.

3.3.4.1 Case Study on Health: Imaging Diagnosis

Imaging diagnosis involves using AI to analyse X-rays in order to provide medical diagnoses. An example is a company known as Envisionit Deep AI in South Africa. This company uses AI for pediatric radiology to assist radiologists with diagnoses. Given the shortage of pediatric radiologists in Africa, Envisionit Deep AI aims to provide an alternative solution. This company focuses on the analyses of X-rays for respiratory and congenital heart disease. These diseases have been identified as the main causes of mortality in children under the age of 5 years old. In a similar initiative in Nigeria, ChestEye has been developed to diagnose tuberculosis from chest X-rays. This is because numerous people are dying from tuberculosis yearly due to the lack of timeous diagnoses as a result of the shortage of radiologists in Africa. Both AI systems are also able to provide radiologists with a priority list of patients based on their conditions.

3.3.5 Energy

Despite steady economic growth in Africa, widening electricity access in Sub-Saharan countries remains problematic. Wind, solar, geothermal, and hydro energy are explored as the main potential solutions to meet fast-growing energy

demand. Many AI applications are developed in Africa to transform renewable energy through increased efficiency. Such efforts are focused primarily on optimising the production, distribution, and consumption of energy; the development of smart grids and intelligent electrical networks and in optimising the performance of solar, photovoltaic, wind, and maritime installations. For example, in Morocco, a model based on multi-layer perceptron (MLP) can predict the evolution of the global monthly solar irradiation. In Nigeria, artificial neural network (ANN) based model are applied for the prediction of solar energy potential. In Algeria, hybrid learning models are forecasting the energy consumption for heating, cooling, and domestic appliances. In South-Africa, ANNs are tested for an appraisal of energy consumption in industrial sectors. Other systems include forecasting and modelling of meteorological data, sizing of photovoltaic systems and modelling, simulation and control of photovoltaic systems using neural networks, fuzzy logic, evolutionary algorithms, and genetic algorithms.

3.3.6 Education

One of the main contributions that AI is making in South Africa is data analytics to predict student performance and identify learning difficulties. For example, identifying potential failure in a particular course and based on this putting mechanism in place to assist learners overcome difficulties is imperative. Similarly, the Virtual University of Senegal with more than 29,340 students is exploiting an e-learning platform with tools to predict the most influential learning objects on the learners' final mark. Additionally, Lainos World developed in Nigeria is a multi-media Geography edutainment software deploying AI with speech synthesis and path navigation. In 2011, with a grant from the Inter-Academy Panel and the Nigerian Academy of Science, the product was localised into French, Spanish, German, Portuguese, Russian, and Chinese languages.

3.3.6.1 Case Study on Education: Learning Analytics for Student Success

Another area in education in which AI is making an impact in Africa is in learning analytics. Learning analytics involves predicting student success or failure rate with the aim of putting in place mechanisms to assist potentially failing students. In South Africa, the Siyaphumelela programme has been launched to employ data analytics that can potentially improve students' success. This project involves 5 South African universities, namely, University of Pretoria (UP), Durban University of Technology (DUT), University of Witwatersrand (WITS), Nelson Mandela University (NMU) and the University of Free State (UFS). The project is funded by the Kresge Foundation to promote the collection and analysis of data for student academic success. The Department of Education Innovation at UP has employed learning analytics to predict academic failure and put in place interventions in order to support students in academic success. A similar initiative has been put in place at the University of South Africa (UNISA) where learning analytics are being used to identify risk modules, perform student profiling, and identify student behaviours and habits. The University of Port Harcourt (UPH) in Nigeria have used learning analytics to predict student failure at schools.



3.3.7 Finance

AI is also significantly contributing to the financial sector. For example, AI has been used by financial institutions and banks in order to determine credit risk when making decisions on granting loans and credit to customers. Financial institutions have also been using AI for fraud detection. In trading, there has been a wide-scale use of AI to predict stock and investment performance. Another area that AI is contributing to is predicting customer churn. In the future, it is anticipated that AI can be used to create automated advisors that can advise clients on different financial options. A South African bank has employed a robot to communicate with clients providing personalised interactions and advise them using voice recognition and human emotion recognition. Similarly, South African start-ups Data Prophet and Clevva use automated advisors to assist clients. Kudi.ai, an AI start-up in Nigeria, uses an AI-driven chatbot to assist users in making payment and send money to their families in Nigeria.

3.3.7.1 Case Study on Finance: Bots for Client

Online bots have made a major impact on banking in Africa. For example, Kudi.ai, a Nigerian based start-up, is making great strides in incorporating AI into banking. The company has developed the chatbot Kudi which assists customers with paying their bills, buying airtime, transferring money, monitoring banking account details, and reminding customers when bills are due. Kudi can be used via any messaging app. A study conducted in 2019 revealed that 7% of financial institutions in Kenya have incorporated the use of chatbots into daily operations for customer interactions. The study also demonstrated that most customers found that interactions with chatbots were a positive experience. Stockshop.co.za is a South African start-up that has been creating bot solutions for stock market investments. One such solution is using chatbots to find suitable financial consultants and brokers for customers. Bots have also been used to conduct real-time identity verification and advise customers based on their financial history and emotional ques.

3.3.8 African culture heritage

Africa is zealous of its heritage. AI can make heritage more visible and accessible for future generations. Aspiration 5 of Agenda 2063 of the Africa we want envisages an Africa with a strong cultural identity. Thus, restoring, conserving, and preserving Africa's cultural heritage is a responsibility towards future generations. Therefore, AI can restore, preserve African heritage, and make it accessible to all, thus bridging between past and present. The preservation and enrichment of cultural heritage will assist in safeguarding thousands of Africa's ancient manuscript. Among them are the slave trade archives, West African documents collection, Timbuktu (Mali), manuscripts from the 17th century, Egypt – Treasures of Dar Al-KutubA from the 17th century, Ethiopia Treasures from National Archives, Senegal Fonds of the "Afrique Occidentale Française" (AOF, 1895-1959), Tanzania National Archives and recently preserving the Mandela documentary memory. The restoration of these old degraded handwritten documents and their digitisation would expose these collections to a wider audience and provide experts with more efficient working methods in terms of information retrieval and content analysis.

3.3.9 Public Service delivery

In most of the African countries, citizens' experience with public services can often be challenging. Public services delivery is characterised by corruption, inadequate supplies, lack of accuracy and transparency, slow response times; and generally poor quality leading to low levels of citizen satisfaction. To address these challenges, public sector organisations can use data science and AI capabilities to deliver policy and generate efficiencies in high-uncertainty environments. However, many policymakers who are to pass and implement the AI systems in their respective countries are anxious about this kind of development; hence, they sabotage such AI-enabled public services delivery implementation. This is attributed to lack of proper information and fear of transparency in AI systems since some private and public sector officials suspiciously benefit from these corrupted and non-transparent systems enabled by the manual systems being utilised in public service offices.

AI technologies can significantly streamline processes and reduce costs in public services delivery. For example, it has the potential to ease administrative burdens, paperwork, and backlogs. Thus, increase public sector efficiency and the speed at which public services can be delivered. Furthermore, it can be used in numerous cases such as anti-money laundering measures through case management and decision making. AI can also be used to achieve client satisfaction for financial services firms. AI systems can be utilised to track customer behaviour and thus offer tailored financial advice. AI systems for financial services in Africa include the bank's Scan to Pay applications developed by the Zenith Bank Plc located in Nigeria. This application can be used by customers to make online and in-store payments in seconds through quick response code scanning on any internet-enabled phone.

3.4 Conclusion

There is overwhelming evidence that AI applications have the potential to dramatically transform the socio-economic development of African countries as well as globally. Thus, AI technologies offer an opportunity for African countries in achieving the AU's Agenda 2063, STISA-2024 and SDG ambitions. But it remains challenging to predict all the technological advances that will be realised as a result of AI. That is why the African Member States need to urgently engage in harnessing these AI-based technologies for their socio-economic development. This includes improving the education system to incorporate AI curricula as well as robust AI research, development, and industrialisation. Even though there exist uncertainties around AIs, sometimes propelled by myths and fake leading to fear and distrust of AI, Africans need to understand that based on historical observations, previous industrial revolutions have undeniably resulted into the transformation of the employment landscape. Thus, the adoption and adaptation of AI for African economies can potentially lead to a robust increase in jobs for the youth, more especially women and girls.

The AU Agenda 2063 provides a framework for guiding Africa's development in the next half a century period, focusing on development on a broad front such as economic, social, political, scientific, and cultural advancement. STISA-2024 places science, technology, and innovation at the epicentre of Africa's socio-economic development and growth, setting as priority areas: eradicating hunger, ensuring nutrition and food security; prevention and control of diseases and ensuring wellbeing; communication (physical and intellectual mobility); natural resources management and climate change; city management and urban waste management, peace, and security; and wealth creation. These priority areas have a bearing on the development of aspirations, in terms of STI-driven solutions for attaining the set development goals. Concurrently, the STISA-2024 priority areas also provide a context for examining the relevance of AI to Africa's development, as AI innovations can be situated within this context. Consequently, some relevant AI use cases can be linked to each of the AU 2063 goals, as shown herein.

The relevance of AI to Africa's development

4.1 Aland STISA-2024 Priorities

According to the STISA-2024 document, six priority areas shall contribute to the achievement of the AU Vision as shown in Figure 4 below. Due to the cross-cutting nature of STI, STISA-2024 was designed to meet the knowledge, technology and innovation demands in various AU economic and social sector development frameworks. STISA-2024 has a leading role to play in increasing efficiency, while eliminating duplication of effort, in the design and implementation of national, regional and African Union policies on STI. The Mission of STISA-2024 is to “Accelerate Africa’s transition to an innovation-led, knowledge-based economy”. This will be achieved through the following objectives:

- Improving STI readiness in Africa in terms of infrastructure, professional and technical competence, and entrepreneurial capacity; and,
- Implementing specific policies and programmes in science, technology and innovation that address societal needs in a holistic and sustainable way.



Figure 3: The six priorities of STISA-2024

Table 1: Linking of AU 2063 Goals with some AI Use

Agenda 2063 Goals	UN SDGs	AI Use Cases
I. A high standard of living, quality of life and well-being for all citizens.	<p>1. End poverty in all its forms everywhere in the world</p> <p>2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.</p> <p>8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.</p> <p>11. Make cities and human settlements inclusive, safe, resilient, and sustainable.</p> <p>The number order on this table does not make sense</p>	<ul style="list-style-type: none"> AI-enabled provision of real-time resource allocation through satellite mapping and data analysis. For example, NARSDA in Nigeria provides satellite images to Agencies and organisations for applications such as meteorology, transportation, agriculture, etc. The analysis of this data using AI techniques enables programs which impact on poverty alleviation. Enabling Agriculture productivity increase through AI predictive analysis from imaging with autonomous drones, and from data, with a knowledge base being used to address the problem of crops loss through waste, overconsumption, and production inefficiencies. For example, in Ghana, the StarShea scheme used AI to build a mobile application to connect women farmers to the global shea nut supply and improved their earnings by over 50% in six months. The use of satellite images and terrain recognition algorithms make it possible to predict a swarm of locusts. This experience has given good results in cooperation with Mauritania. AI augmentation and targeted automation with intelligent devices can improve the work environment, increase productivity, and be a significant driver of economic growth. AI innovation-based Start-ups with emerging entrepreneurs, enabling job creation, and reducing youth unemployment. The AI of Everything, the digital AI mesh, fed by the ubiquitous IoT, smart devices, and wearables, enabling smart
2. Well educated citizens and skills revolution underpinned by science, technology, and innovation.	<p>4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.</p>	<ul style="list-style-type: none"> AI-enabled virtualised, intelligent mentors and responsive personalized learning, revolutionising education and improving participation and outcomes. E-Education providers such as Coursera using AI-produced granular information for effective learning. Educational data mining and big data analytics tools, improving graduation rates of students with low-income backgrounds, spotting warning signs before dropout to allow targeted interventions. For example, Kenya Arius's AI-enabled chabot's-based education technology leveraging personalised learning on mobile devices, providing access to information on topics such as farming, entrepreneurship or financial literacy to the world's least served; in Nigeria, Lainos International developed a word-processor for several African languages which is being used to provide literature in indigenous languages. Generally, AI-enabled quality education delivery through e-Learning, becomes all the more important, given the reality of the impact of Corona Virus Disease 2019 (COVID-19) pandemic

Agenda 2063 Goals	UN SDGs	AI Use Cases
3. Healthy and well-nourished citizens.	3. Ensure healthy lives and promote well-being for all at all ages.	<ul style="list-style-type: none"> AI-enabled significant improvement in preventative healthcare programmes and diagnostics, leading to new scientific breakthroughs. AI-enabled smartphone mobile devices, being used to diagnose heart, eye, and blood disorders; AI-driven online conversation agents and machine vision, can extend access to millions of people and remotely diagnose various health conditions using images from the cameras of everyday smartphones. AI technology used to better understand patterns in the spread of disease, as well as design more effective public health measures in response. Example of Analysis of Breast Cancer Using AI Image Processing Techniques. For example, Sophie Bot, a Kenyan start-up, using AI-driven chabot to provide a platform for questions on sexual and reproductive health. In a society where talking about sexual health is often a taboo; AI-enabled drones being used to deliver health services in rural Rwanda, in Uganda, Mbarara University of Science and Technology is developing an AI-empowered digital pathology platform for automated analysis of pap-smears images for diagnosis and classification of cervical cancer.
4. Transformed economies.	8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> AI augmentation and targeted automation with intelligent devices can improve the work environment, increase productivity, and be a significant driver of economic growth. AI innovation-based start-ups with emerging entrepreneurs, enabling job creation, and reducing youth unemployment. New hybrid manufacturing incorporating AI of Everything, Internet of Things (IoT) sensors, 3D and 4D printing, reshaping industries and yielding exponential innovation; traffic-light networks optimisation using AI-enabled real-time traffic camera data and IoT sensors to maximize vehicle throughput. AI being used to schedule predictive maintenance of public transportation systems, such as trains and public infrastructure (including bridges), to identify potentially malfunctioning components. For example, South African AI-based OMNI of data prophet reshaping the manufacturing industry product quality control.
5. Modern agriculture for increased productivity and production.	2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.	<ul style="list-style-type: none"> Enabling agriculture productivity increase through AI predictive analysis from imaging with autonomous drones, and from data, with a knowledge base being used to address the problem of crops loss through waste, overconsumption, and production inefficiencies. For example, in Ghana, the StarShea scheme used AI to build a mobile application to connect women farmers to the global shea nut supply and improved their earnings by over 50% in six months. The use of satellite images and terrain recognition algorithms make it possible to predict a swarm of locusts. This experience has given good results in cooperation with Mauritania.

Agenda 2063 Goals	UN SDGs	AI Use Cases
6. Blue/ocean economy for accelerated economic growth.	14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.	<ul style="list-style-type: none"> AI-based pattern recognition tracking marine-life migration, population levels, and fishing activities to enhance sustainable marine ecosystems and combat illegal fishing.
7. Environmentally sustainable and climate-resilient economies and communities.	<p>6. Ensure availability and sustainable management of water and sanitation for all.</p> <p>7. Ensure access to affordable, reliable, sustainable, and modern energy for all.</p> <p>13. Take urgent action to combat climate change and its impacts.</p> <p>15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.</p>	<ul style="list-style-type: none"> AI being used to track land-animal migration, population levels, and hunting activities to enhance sustainable land ecosystems and combat illegal poaching. AI-enabled satellites images processing to determine the health of forests and water resources and monitor harvests and agriculture everywhere. AI-driven analysis of satellite data to map and predict the progression of wildfires and thereby optimise the response of firefighters. Prediction of climate-related problems and disasters through AI-enabled climate modelling and climate change data analysis. Numerical modelling and simulation of sand dune forming processes are conducted to fight against the advancement of the desert and the road maintenance in Sahara. AI-driven real-time analysis, enabling green energy in all its forms, continuously improving for increased output and more efficiency. For example, in Lagos, Vanpeux Global Synergy Company provides AI-enabled solar power solutions. AI tools are experimented in some African countries for forecasting energy consumption and optimising the performance of solar, photovoltaic and wind installations (Nigeria, Morocco, Algeria, South-Africa) The Internet-of-Things (IoT) and sensors networks feeding into the AI of Everything, predicting sanitation and consumption patterns for improved safe water and sanitation provisioning. AI- enabled water pipe leakage monitoring, and controlled irrigation, reducing water wastage, developed at the Tshwane University of Technology, South Africa. Another example is AI-enabled smartphone-based spatial wave application for garbage collection drivers to map and record their daily routes and by citizens to report clean-up issues, enabling drivers to complete their routes faster and respond to more customer requests.
8. A United Africa (Federal or Confederate).	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.	<ul style="list-style-type: none"> AI application to reduce discrimination, corruption and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.
9. Continental financial and monetary institutions established and functional.	9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> AI application to reduce discrimination, corruption and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the Cyber Kill Chain, in a manner not possible before.

Agenda 2063 Goals	UN SDGs	AI Use Cases
10. World-class infrastructure criss-crosses Africa	4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> • New hybrid manufacturing incorporating AI of Everything, Internet of Things (IoT) sensors, 3D and 4Dprinting, reshaping industries and yielding exponential innovation; Traffic-light networks optimisation using AI-enabled real-time traffic camera data and IoT sensors to maximise vehicle throughput. AI being used to schedule predictive maintenance of public transportation systems, such as trains and public infrastructure (including bridges), to identify potentially malfunctioning components. For example, South African AI-based OMNI of Data Prophet reshaping the manufacturing industry product quality control.
11. Democratic values, practices, universal principles of human rights, justice and the rule of law entrenched.	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.	<ul style="list-style-type: none"> • AI application to reduce discrimination, corruption, and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.
12. Capable institutions and transformative leadership in place.	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.	<ul style="list-style-type: none"> • AI application to reduce discrimination, corruption, and drive broad access to e-government, personalized, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.
13. Peace, security and stability is preserved.	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.	<ul style="list-style-type: none"> • AI application to reduce discrimination, corruption, and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.
14. A stable and peaceful Africa.	9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> • AI application to reduce discrimination, corruption, and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.
15. 15. A fully functional and operational APSA	9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> • AI application to reduce discrimination, corruption, and drive broad access to e-government, personalised, and responsive intelligent services. AI enabling significantly staying ahead of global cyber threats, the cyber kill chain, in a manner not possible before.

Agenda 2063 Goals	UN SDGs	AI Use Cases
16. African cultural renaissance is pre-eminent.	14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development. 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	<ul style="list-style-type: none"> AI, can restore, preserve African heritage, and make it accessible to all, bridging between past and present. The preservation and enrichment of cultural heritage will help in Safeguarding thousands of Africa's ancient manuscript among them: the slave trade archives, West African documents collection, Timbuktu (Mali), manuscripts from the 17th century, Egypt – Treasures of Dar Al-KutubA from the 17th century, Ethiopia Treasures from National Archives, Senegal Fonds of the «Afrique occidentale française» (AOF, 1895-1959), Tanzania National Archives and recently preserving the Mandela documentary memory.
17. Full gender equality in all spheres of life.	5. Achieve gender equality and empower all women and girls.	<ul style="list-style-type: none"> AI-enabled empowering of women for growth and new opportunities, through identifying and correcting for gender bias, further automating/augmenting tasks. For example, in Ghana, the StarShea scheme used AI to build a mobile application to connect women, farmers, to the global Shea nut supply and improved their earnings by over 50% in six months. Also, AI- enabled digital pathology platform for automated analysis of pap-smears images for diagnosis and classification of cervical cancer, among women and girls in Uganda.
18. Engaged and empowered youth and children.	4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. 5. Achieve gender equality and empower all women and girls.	<ul style="list-style-type: none"> AI-enabled empowering of women for growth and new opportunities, through identifying and correcting for gender bias, further automating/augmenting tasks. For example, in Ghana, the StarShea scheme used AI to build a mobile application to connect women, farmers, to the global Shea nut supply and improved their earnings by over 50% in six months. Also, AI- enabled digital pathology platform for automated analysis of pap-smears images for diagnosis and classification of cervical cancer, among women and girls in Uganda. AI-enabled virtualised, intelligent mentors and responsive personalized learning, revolutionising education and improving participation and outcomes. E-Education providers such as Coursera using AI-produced granular information for effective learning. Educational data mining and big data analytics tools, improving graduation rates of students with low-income backgrounds, spotting warning signs before dropout to allow targeted interventions. For example, Kenya Arius's AI-enabled chabot's-based education technology leveraging personalised learning on mobile devices, providing access to information on topics such as farming, entrepreneurship or financial literacy to the world's least served; In Nigeria, Lainos International developed a word-processor for several African languages which is being used to provide literature in indigenous languages. Generally, AI-enabled quality education delivery through e-Learning, becomes all the more important, given the reality of the impact of COVID-19 pandemic resulting in closing academic institutions that constrained face-to-face delivery.

Agenda 2063 Goals	UN SDGs	AI Use Cases
19. Africa as a major partner in global affairs and peaceful co-existence.	17. Strengthen the means of implementation and revitalise the global partnership for sustainable development.	<ul style="list-style-type: none"> Multi-sectoral collaboration is essential for the safe, ethical, and beneficial development and use of AITs. ITU-facilitated “AI for Good Global Summit,” bringing together governments, industry, academia, and civil society, to explore the responsible development of human-centric AI in solving humanity’s grand challenges, including accelerating the SDGs. CGIAR’s platform for big data in agriculture, uniting agricultural research institutes and companies with the goal of closing the digital divide between farmers in developed and developing countries.
20. Africa takes full responsibility for financing her development Goals.	10. Reduce inequality within and among countries. 17. Strengthen the means of implementation and revitalise the global partnership for sustainable development.	<ul style="list-style-type: none"> Human augmentation using AI-enabled devices both internally and externally provides super senses and knowledge, enhanced physical capabilities, and corrects disabilities, yielding a more equal and inclusive society. For example, CGIAR’s platform for big data in agriculture, uniting agricultural research institutes and companies with the goal of closing the digital divide between farmers in developed and developing countries. Multi-sectoral collaboration is essential for the safe, ethical, and beneficial development and use of AITs. ITU-facilitated “AI for Good Global Summit,” bringing together governments, industry, academia, and civil society, to explore the responsible development of human-centric AI in solving humanity’s grand challenges, including accelerating the SDGs. CGIAR’s platform for big data in agriculture, uniting agricultural research institutes and companies with the goal of closing the digital divide between farmers in developed and developing countries.



4.2 Some guidelines for harnessing AI for Africa's development

Driven by the foregoing principles set out in the previous sections, the following guidelines should be considered.

4.2.1 AIT needs assessment framework

An analysis of the history of computing technologies shows that technological change is exponential, and this is in line with Ray Kurzweil's "Law of Accelerating Returns" (Kurzweil, 2000). That is, as time passes, technology changes faster. This phenomenon is observed in the advances in AI technologies. Therefore, this demands that both the current technology landscape, as well as its ebbs and flows, should be clearly understood. Hence, Africa's ability to own the future of the AI technologies in its own developmental goal's context requires a mastery of the change. This is because, AI technologies are causing changes to the technology landscape, creating new segments, such as self-driving cars, destroying existing segments, such as GPS trackers, and transforming some segments, such as automobiles. Thus, for Africa to maximally harness AI for its developments, there is the need for capacity to identify, utilise, and shape the emerging AI technologies in Africa's context. Consequently, decisions to either embrace or ignore what aspect of AI, must be made, as the changes in the landscape continue to unfold. This means Africa must embrace AIST through investing, utilising and contextually shaping the AI technology to the continent's challenges. Either choice, if picked wrong, can be costly. So, the development of a framework for assessing AIT needs for Africa's development is imperative.

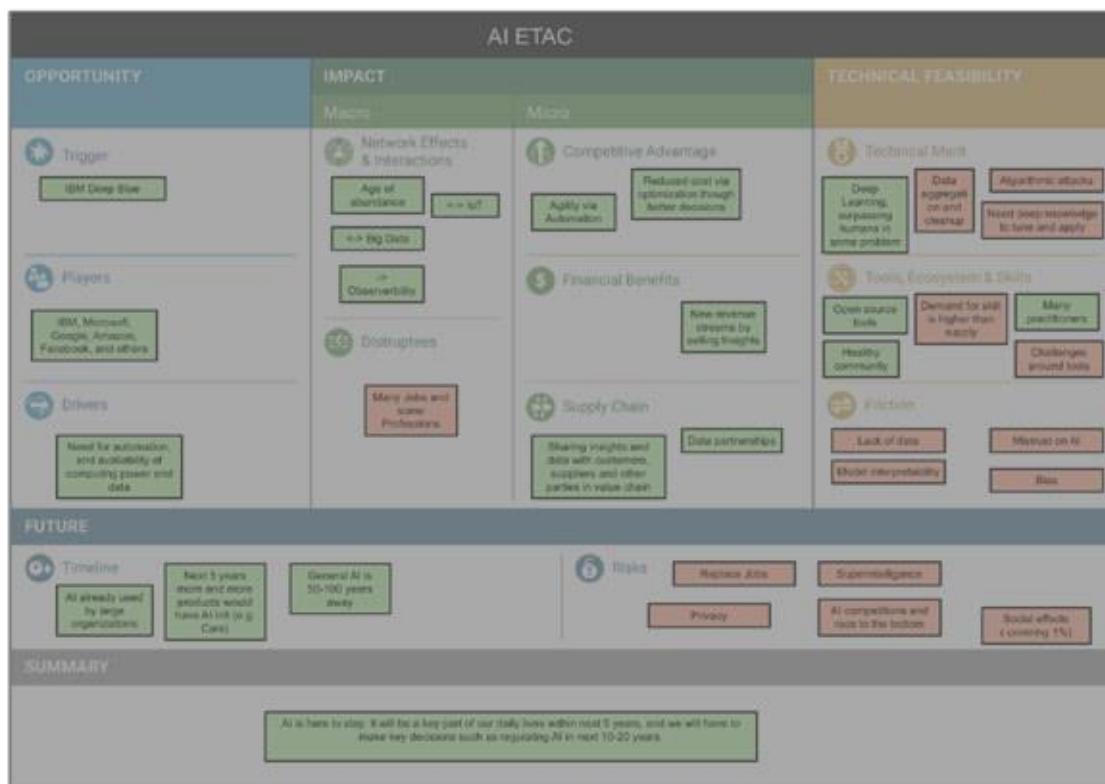


Figure 4: AI ETAC (Emerging technology analysis canvas) framework (Perera, 2018)

Figure 4 above shows a Perera's AI ETAC (Emerging Technology Analysis Canvas) framework that provides a guide for AI technology needs assessment framework (Perera, 2018). By using this AI ETAC framework as a guide, Africa should be able to; a) make it easier to decide on what aspects of AI to include and which ones to exclude; b) provide a shared understanding that enables an easier discussion towards an intelligent AIT analysis among stakeholders, communicate and educate others and learn from others, about the AI technology; c) facilitate appropriate contextualisation of the AIT development and adoption, reflecting the realities of the African development aspirations; d) provide mechanisms for engaging in the long-term adaptation of the technology, as well as the study of AIT effects, and; e) be amenable to adaptive evolution. Further guided by Perera's AI ETAC, the proposed AI technology needs assessment framework for Africa, should be subject to several conditions, which include trigger, impact, feasibility, and risks conditions. These can be arranged around a logical narrative that probes the AI technology in the African context. Trigger condition deals with the identification of developmental needs and related AI innovations that address those needs, albeit, bearing in mind that often, the innovation could change the initial perception of the problem. Impact condition is that AI technology should have a significant potential impact. Feasibility condition is that the feasibility of the AI technology, vis-à-vis the available resources, should not be in doubt. Risks condition is that AI technology must navigate risks related to technology development and adoption.

4.2.2 Supportive infrastructure

Deliberate investment in connectivity infrastructure is a sine qua non to a productive AI for Africa's development. The availability of robust, ubiquitous, and affordable communication and power supply infrastructure is imperative. Without this, AI's potential benefits will be limited to and enjoyed only by a few privileged elites. This is further elucidated to, later in this report.

4.2.3 Regulatory and policy framework

It is critical to have policies and regulatory frameworks in place that promotes productive AI harnessing, by encouraging innovation and investment. AU should encourage African governments to take a deliberate and proactive approach, to implement supportive regulation, policies, and initiatives. There are several areas relevant to the development of AI-enabled robust digital economies, where policymakers should focus. This is elaborated upon in later part of this report.

4.2.4 Creating a collaborative environment

Taking a cue from leading countries in AI, African governments should create enabling environments for increasing cooperation and exchange of information between Quadruple helix stakeholders. This should allow for the different stakeholders to work together, rather than in silos. Such a collaborative approach could facilitate the sharing of expertise and perspectives on AI. African governments can acquire a deeper understanding of the AI technology, by drawing on international but contextualised best practices, to address specific local and regional African needs. This approach could ensure that policy and regulatory action protects citizens while supporting AI technology development. Furthermore, multi-sectoral collaboration is essential for the safe, ethical, and beneficial development and use of AI technologies. Africa should not be left behind in active participation, positing African perspective, in the ITU-facilitated AI-for-Good Global Summit series, which brings together relevant stakeholders, to explore responsible development of human-centric AI. This can be carried out so to solve African grand challenges and accelerate AU's development aspirations. Specific recommendations on this are provided in the latter part of this booklet.

4.3 Conclusion

As Africa aspires to develop through a framework provided by the AU's Agenda 2063 for the next half a century period, African governments should focus development on a broad front such as economic, social, political, scientific, and cultural advancement. This can be achieved in alignment with the STISA-2024, a programme derived from Agenda 2063, which places science, technology, and innovation at the epicentre of Africa's socio-economic development and growth. African countries should set national AI-driven priority areas towards eradicating hunger, ensuring nutrition and food security, preventing, and controlling diseases and ensuring the wellbeing of its citizens. Special emphasis should be placed on communicating their physical and intellectual mobility and translate it into developmental strategies. Furthermore, there is a call to utilise and channel Africa's natural resources into AI's manufacturing, which could make AI technology much cheaper. This can in-turn improve Africa's STI readiness with respect to infrastructure, professional and technical competence, and entrepreneurial capacity. Such an approach can also promote the implementation of specific policies and programmes in science, technology and innovation that address societal needs in a holistic and sustainable way. Moreover, Africa's collective efforts cannot afford to continue with the habit of seeking for already-made solutions, from some other contexts attempting to counter African problems, as a matter of course. Notably, African challenges must be addressed by African solutions, specifically designed towards an African context. Thus, Africa must strategically utilise contextualised ideas such that they significantly consider the realities of the African socio-cultural and economic contexts.

Policy regulatory and strategic considerations about Africa should be designed with regard to AI. Thus, it is essential to situate AI in regional, continental, and global frameworks. This section begins by exploring regional and continental frameworks that are of particular interest to AI and then focuses on the global context. Possible gaps in the regional and continental frameworks are highlighted. Taking the view that frameworks influence strategy, strategy informs policy and policy drives regulation, the section starts by looking at regional and continental frameworks. Furthermore, this section then elaborates on key policy issues that arise from the introduction of AI and what policymakers should thus pay attention to. Examples of policies are provided, and the section ends with a checklist of policy options as a reference. Moreover, legal and regulatory aspects related to AI are also presented in the context of the key application areas/use cases identified. While this approach makes it easier to contextualise, general and common legal and regulatory issues are presented as a preamble to the more specific discussion. The section ends with a checklist of key legal and regulatory issues pertaining to AI.

Policy and regulatory consideration

5.1 AI strategies

In this section, the main elements that governments need to take into consideration in developing or enhancing AI and AI-related strategies were considered. The section also considered some examples of existing AI strategies currently in existence or under development in Africa. For instance, Canada has been cited as one of the first countries to have a national strategy on AI. Canada committed \$125 million over 5 years aimed at developing research capacity, establishing Centres of Excellence, and providing thought-leadership on issues of economics, ethics, policies, and laws. On the other hand, China has over the years released several strategy and policy documents relating to AI with the ultimate goal of becoming the global power in AI by 2030. Focusing specifically on AI, the government in 2017 issued the “Next Generation Artificial Intelligence Development Plan”. China’s strategy focuses on enhancing its competitiveness, national security, and general socio-economic development. Specific actions centre on innovation-driven development, integration of AI into the economy and development of an ecosystem underpinned by knowledge clusters, technology clusters and industry clusters.

Through its BRAIN (Building a Responsible AI Nation) strategy, the United Arab Emirates (UAE) aims to be a global leader in the responsible use of AI by 2031. In line with these ambitions, the UAE is the first country to have a Minister of State for Artificial Intelligence who leads a Council on AI comprised of Director-Generals of government institutions and ministries. The Council is charged with accelerating AI adoption through policymaking, advancing research and promoting public-private collaboration. It represents a multi-stakeholder and multi-disciplinary approach to AI development which Africa should replicate. In 2018, Russia’s Ministry of Defence developed a 10-point action plan for AI which included a focus on partnerships across public and private institutions. This was aimed at building laboratories and undertake research, conduct training, and develop expertise as well as the development of a national centre on AI. Building on this plan, Russia is working to finalise a national AI strategy by mid-June of 2020. In the USA, an executive order for the development of the American AI Initiative was issued in February 2019. The Initiative will focus on research, workforce development and international cooperation. While welcoming the initiative, critics point to the lack of additional investment and focus on regulation as well as concrete actions by the government. This is showing weaknesses in the adoption of AI-based on the US government’s approach. However, it should be noted that the US Department of Defence had an AI strategy dated 2018 and this was released in 2019 after the Executive order. The US government has since created a platform to track all AI initiatives.

Turning to African countries, there is no country so far that has developed a specific strategy on AI. However, most African countries have mostly termed AI-related strategies that touch on AI in the context of general ICT development, 4IR, blockchain technology, and more. One notable example is the government of Kenya, which in 2018 established a taskforce on blockchain and AI technologies and has since produced its report in late 2018. The task force was charged with providing recommendations and a roadmap on the integration of these technologies. Recently, the government announced that it would use AI to assess applications for its affordable housing initiative. Even though there is no strategy or policy document on AI, South Africa supports the Centre for AI Research (CAIR) as part of its research, development, and innovation roadmap. This is similar to Nigeria’s strategy, where the Data Science Nigeria platform launched an AI hub at the University of Lagos in 2018. In Ghana, Google has opened an AI centre which houses researchers from 12 countries working on the application of AI focusing on agriculture and education among other sectors.

In developing their strategies, African countries will need to think about pre-conditions for successful AI implementation and these include:

- Physical infrastructure;
- Regulatory and policy framework;
- National and regional research systems;
- Social responsibility;
- Education systems and standards; and
- Intellectual property regimes.

As African countries move towards the development of strategies dealing with AI, the importance of regional and international cooperation cannot be overemphasised. Through the African Union and its Regional Economic Communities, Africa's development has to a large extent follow the principles of regional integration. This is important for AI in that it would enable countries to pool resources, develop common frameworks and standards and share access to data. As countries progress in AI implementation at different levels, the role of AUDA-NEPAD Agency will be to monitor the developments and ensure that all member states are moving towards a common goal in the AI sector. Furthermore, global cooperation will also be needed to ensure that Africa's policies and strategies are aligned with the rest of the world.

The case of government agility in providing an enabling environment is exemplified by the Government of Rwanda which amended its civil aviation regulations to permit a drone delivery service. This drone service delivery allows for the supply of medication and blood to remote areas of the country. That is why every region across the world is looking at leveraging their unique abilities towards leading in AI-inspired technologies. For example, China is betting on its population size and size of data it collects. It then operates as a unified central government and allocate its large amounts of funds towards AI. The USA is leveraging the number of talents and top tech companies it has. The question then becomes: what could be Africa's unique leverage? The answer is the growing population of young people Africa has. It has been reported that 60% of Africa's population is below the age of 25, making it the youngest continent in the world according to the United Nations World Population Prospects (2017 Revision). Africa is further projected to grow by 42% by 2030 according to the United Nations Department of Economic and Social Affairs (Population Division, May 2015). So, the biggest potential AI strategy for Africa could be that by 2063, 50 million young Africans could be skilled in AI, Data Science, and other Industry 4.0 technologies. Then these young Africans can then meet the globally growing demand for AI skills.

5.2 Guiding principles

5.2.1 Principle of S&T development and transfer

Some principles of S&T development and transfer are of relevance, in the quest to harness AI for Africa's socio-economic advancement. These principles have indicated that AI Science and Technology (AIST) is; (a) universal and particular, (b) problem-solving, and (c) interactive. The universality and particularity of AIST are that the conceptual knowledge of AI remains the identical world-wide, and the contextual knowledge of the AI is applicable in each domain of socio-cultural and economic context, respectively. Both conceptual and contextual knowledge is required for appropriate AI solution provisioning, in any given context. This implies that any transfer of AIT must be accompanied by the transfer of its science. Notably, AIST is problem-solving in that any problem to which an AI solution applies, and therefore must be contextually defined. Hence by implication, an AI solution provided in one context cannot be directly extrapolated into another context, without adaptation. Otherwise, model mismatching may result in obvious complications. Since AIST is interactive, it allows for AIT to engage in real-time problem-solving in an AI application context and afford the validation of its strength and limitations to be assessed. Such contextual limitations could then be appropriately managed and re-examined for underpinning science that can be utilised for corrections and further development.

5.2.2 Principle of African solutions to African problems

Africa's collective efforts cannot afford to continue with the habit of seeking for already-made solutions, from some other contexts attempting to counter African problems, as a matter of course. It should be noted that African problems are African context defined, and so, should be the approach to AI solution provisioning, which should be African home-grown. The principles S&T development and transfer are espoused in Sub-Section 2.5.1.1 have a bearing on this. In this regard, the following statement in the European Commission's (EC) "Declaration on Cooperation on AI," is instructive (België, 2018). The statement made was: "Ensuring an adequate legal and ethical framework, building on European Union (EU) fundamental rights and values, including privacy and protection of personal data, as well as principles such as transparency and accountability." This statement implied that the EC wants to harness the power of AI, by adopting a Euro-centric approach and providing a European solution to a European problem. Taking a cue from this EC approach, as much as Africa can borrow ideas from the range of issues considered in the strategies of other nations, the usage of the ideas has to be contextualised in such a way that significantly considers the realities of the African socio-cultural and economic contexts.

5.2.3 Principle of diversity-aware

Diversity is an intrinsic heritage of Africa. As conceptualised for the context of AI for Africa's development, diversity-aware principle posits that African diversity should be positively managed, maintained and exploited, rather than being treated as an aberration to be ignored. Thus, this warrants attainment of unity through diversity management. The principle is a reverse-globalisation approach, whereby one-size-fits-all thinking is discouraged, and the strategy evolution is bottom-up rather than top-down. Thus, adopting a federated strategy for harnessing AI for Africa's development is highly advocated for. A federated strategy abstracts the aspect that is universal Africa-wide, to the AU level, while aspects specific to each of the national constituents are handled at the national levels. The diversity-aware principle will facilitate teaming up of African nations so that the opportunities of AI for Africa's socio-cultural and economic development can be maximally exploited, while the challenges can be dealt with collectively.

5.2.4 Principle of social management of AI

The principle of social management of AI recognises a key element of the African heritage, which is a social world view, based on human beings. It posits that AIT is more than just the hardware and software artefacts, but rather a social process. This means that it focuses on human needs and wants, which are the ends. This principle acknowledges that AIT, like any other technology, has side effects, which could be social, cultural, economic, and political effects. It further acknowledges that AIT is not value-free, as it seems naïve to separate the existence of AITs from the uses to which they are put, nor from the values of their creators. Most importantly, this principle acknowledges that AIT is not inherently good or bad, rather it is humanity's use of that technology that could render it evil or virtuous. Therefore, the principle advocates for harnessing AI for Africa's development, in a socially responsible manner. This is carried out by enacting a deliberate strategy for managing the AIT risks, creators (individual and institutional), and the future of the technology against the environment and humanity. In such a strategy, an appropriate balance must be struck between maximising the exploitation of its beneficial opportunities and minimising the risks.

5.2.5 Principles of AI for good of all

The AU's development aspirations set in Agenda 2063 is to "build an Africa whose development is people-driven, relying on the potential offered by people, more especially its women and youth and caring for children". The International Telecommunication Union (ITU), in collaboration with other organisations, has been championing for a series of Global Summits on AI for Good. Going by these, AI for Good of All should be set as a principle, in harnessing AI for Africa's development. The AI harnessing should be implemented such that it is human-centred and placing this principle at the heart of

the strategy. Therefore, it should be ensured that responsible AIT development and applications are aligned with ethical values, while users are being empowered. Towards this end, inspiration can be drawn from a recent report of the UK House of Lords (UK-HoL, 2018), in setting some basis for such a principle viz: AITs should; a) be developed for the common good and benefit of humanity; b) operate on principles of intelligibility and fairness; c) not be used to diminish the data rights or privacy of individuals, families or communities; d) be open for all citizens to be educated to enable them to flourish mentally, emotionally and economically alongside AI; e) never be vested with the autonomous power to hurt, destroy or deceive human beings; rather, open to subjecting the decision of the creators to transparency, liability, accountability, justification, and redress. The overarching principle of AI for the good of all is essential to foster trust in AI and ensure that its true potential can be realised by all.

5.3 Legal and regulatory issues

In the realm of AI, legal and regulatory issues revolve largely around privacy, security and human rights concerns linked to the data used by AI applications as well as the way in which AI-enabled services and applications work.

Some of the legal and regulatory issues that AI will need to address

- Infringement on human rights due to biases that may exist in AI-enabled applications
- Privacy concerns with open data such as that embodied in the open-data open-government movement
- Interoperability and portability of data such that applications can work seamlessly in different countries/environments. Security of AI-enabled systems
- The liability of AI-enabled systems when things go wrong
- Dealing with so-called “evil AI” which is designed with malicious intent

5.4 Actionable regulatory recommendations considerations

Here is a list of actionable regulatory recommendations for consideration by African Member

- Development of proactive regulations on AI in politics, warfare, and healthcare: Not all sectors require their own specific AI regulations. However, the use of AI in politics, warfare and healthcare holds a lot of power and can pose a lot of threat, requiring they have their own separate regulations.
- Implement highly restrictive regulations on the use of deep fakes and fake news, especially in politics.
- The use of counter methods in the detection of deep fakes and fake news
- African countries joining the ban on the development and use of “offensive autonomous weapons.” This ban as highlighted by the United Nations’ Convention on Conventional Weapons (CCW) meetings on lethal autonomous weapons, as well as “An Open Letter to the United Nations” and “Convention on Certain Conventional Weapons” (International Joint Conference on AI (IJCAI 2017).
- Development of an AU AI for health regulatory framework that adopts and extends multilateral work being done by organisations including the ITU and WHO Focus on AI for Health (FG-AI4H) and the International Medical Device Regulators Forum (IMDRF).
- Adoption of precision evaluation by regulatory bodies and AI manufacturers - AI systems should be assessed and benchmarked with precision across all demographics and their intersectionality that they are intended to be used for. Africa has a lot of diversity across nationalities and ethnicities; thus, AI systems should ensure that they capture such diversity of a country or region in their data model before deploying. Precision Evaluation is a good approach to that measure (Akogo, 2020). The use of assessment platforms by regulatory bodies and AI manufacturers as well for the rigorous testing of AI systems, especially in the Healthcare sector.
- Development of agnostic data governance guidelines and framework to be adopted and further customised by every government agency, private businesses, and academia. This should include internal data warehouse, data integrity, privacy, and security.

African countries will need to examine how AI is placed in relation to existing laws and what changes will need to be enacted as the technology is adopted and adapted. This will have to take cognisance of global laws such as the European Union General Data Protection Regulation (EU GDPR) which as previously mentioned is concerned with data privacy. Therefore, in regulating AI, African countries will need to focus on several dimensions including the regulation of AI itself, the regulation of specific industries that use AI such as self-driving vehicles, and self-regulation through standards and codes of practice. While formal AI regulatory systems are being developed, Africa should consider soft regulation in the form of guidelines and principles.

The Organisation for Economic Co-operation and Development (OECD) has recently released the following principles with five points emphasising that:

- AI should benefit people;
- AI systems should respect rule of law, human rights, and democratic values;
- There should be transparency and disclosure;
- AI systems should be robust, secure, and safe; and
- Developers and implementers of AI systems should be held accountable in upholding these principles.

The OECD principles have been signed by the 36 OECD members and 6 South American countries. The Future of Life Institute has 23 AI principles categorised under 3 broad headings: Research, Ethics and Values, Long-term issues.

Signatories to these principles are mainly individuals, academics, and industry/technology companies. While not taking away from these global initiatives, Africa should consider framing its own guidelines and principles and this will require leadership from member states. Apart from determining the laws and regulations that are needed, African countries will need to look at the institutional architecture that will support enforcement and compliance and determine what implications this has on resources and capacity. The lack of capacity, skills and expertise is one possible reason for the lack of policies and accompanying legal and regulatory frameworks that should be instated in order to deal with AI.

5.5 The AI policy space

Policy interventions are required in Africa that will accelerate the uptake of AI in a way that serves Africa's socio-economic developmental needs. In developing AI policies, African governments should consider the overarching intent and priorities for their countries. This must include growth of their economy, capacity and skills development, industrialisation, diversification of the labour market. To systematically achieve this, AI policies can be categorised as direct, indirect, or AI-relevant. Direct AI policies are those policies aimed specifically at AI technologies. Indirect policies are those that affect AI without focusing directly on the technology. An example of indirect policy would be intellectual property policies and laws. AI-relevant policies are those policies that are affecting associated sectors linked to or affected by AI. This is where Africa might need to spend more effort as countries focus on the impact of AI on education, health, agriculture, finance, mining, industrialisation, among others.

While learning from what other countries and regions are doing, Africa will also need to contextualise AI policy frameworks so that AI development and associated resources are channeled to the right priorities. In the same way that discussions on AI are focusing on how AI can support the SDGs, Africa should consider how it can support attainment of the goals of Agenda 2063. The following are proposed recommendations on the AI policy space for Africa:

- 50 million young Africans should be skilled in AI, data science, and other industry 4.0 technologies. These young Africans can then meet the globally growing demand for AI skills;
- Governments should partner, fund and scale existing AI capacity-building efforts across the continent. This includes initiatives from organisations including Runmila AI Institute, Data Science Nigeria, Deep Learning Indaba, Zindi Africa and AI Expo Africa;

- Partnerships should be developed between these private initiatives and universities in order to establish more effective AI and industry 4.0 curriculums and programmes within African tertiary institutions;
- Initiate and support existing AI competitions and hackathons;
- Attract international AI summits, conferences, and workshops to Africa, leading to knowledge transfer and international partnerships for our local AI ecosystem. This includes hosting conference on Neural Information Processing Systems (NeurIPS), World Summit AI, International Conference on Machine Learning, International Conference on Machine Learning (AAAI), International Conference on Computer Vision (ICCV) and others in Africa and ensuring the involvement of local talents.
- Invest in practical STEM/Digital skill education
- Initiate African supercomputing/HPC project for advanced AI research in medicine, genomics, agriculture and transport;
- Ensure all initiatives include substantial percentages of women and girls;
- Initiate and support existing AI start-up competitions and hackathons;
- Start an African Union AI and Industry 4.0 Fund startups;
- Governments should adopt African developed AI solutions to solve local challenges, especially for climate smart agriculture and evidence-based healthcare;
Create a conducive regulatory environment for AI start-ups and business. This would include regulations that prevent abuse of AI but also allows for innovation (see regulatory considerations for more (8.2)); Individual African Member States should initiate open data initiatives similar to the Ghana Open Data Initiative (GODI),
- which would provide the African AI ecosystem with the needed data to build their AI and machine learning systems; African Union should have a continental open data initiative that combines data from each country's open data initiative
- with a common standard, to create bigger datasets;
Investment towards AI hardware accelerators;
- Incentivise businesses and organisations around the world to outsource their AI and data science needs to Africa for affordable, quality, and fast development. This should be similar to what China did for manufacturing and India is doing for software development;
Consideration of universal basic income for when AI development and adoption grows in Africa;
- Reskilling workforce towards augmented intelligence - the use of AI and other 4IR tools by professionals to increase productivity - through existing and new digital skilling initiatives;
Investment towards the use of AI and Industry 4.0 for climate change adaptation and mitigation; and
- Initiation and support of existing projects on the use of Natural Language Processing (NLP) for the digitisation of African languages.

5.6 Conclusion

AI policy regulatory and strategic considerations about Africa should be designed for national, regional, continental, and global frameworks. Frameworks influence strategy, strategy informs policy and policy drives regulation. In developing their strategies, African countries will need to think about pre-conditions for successful AI implementation. These include physical infrastructure, regulatory and policy framework, national and regional research systems, social responsibility, education systems and standards, intellectual property regimes. Moreover, African countries will need to examine how AI is placed in relation to existing laws and what changes will need to be enacted as the technology is adopted and adapted. This will have to take cognisance of global laws such as the European Union General Data Protection Regulation (EU GDPR) which as previously mentioned is concerned with data privacy. Therefore, in regulating AI, African countries will need to focus on several dimensions including the regulation of AI itself, the regulation of specific industries that use AI such as self-driving vehicles, and self-regulation through standards and codes of practice. While formal AI regulatory systems are being developed, Africa should consider soft regulation in the form of guidelines and principles . Policy interventions are required in Africa that will accelerate the uptake of AI in a way that serves Africa's socio-economic developmental needs.

In developing AI policies, African governments should consider the overarching intent and priorities for their countries. This must include growth of their economy, capacity and skills development, industrialisation, diversification of the labour market. This is where Africa might need to spend more effort as countries focus on the impact of AI on education, health, agriculture, finance, mining, industrialisation, among others.

Admittedly, there are risks and challenges that are associated with AI implementation in socio-economic growth, however, this reality should not obstruct the fact that there are several opportunities for economic growth. Thus, because of the opportunities associated with AI, several AI-based public and private institutions have employed dedicated AI-based applications' developers. Examples include AI-based marketing techniques that aimed at maximising marketing for small business and focusing on achieving high marketing strategies. This has led to increased interest and investment by numerous businesses trying to take opportunities in AI-based marketing activities that can potentially deliver the highest return on investment. AI-based marketing solutions have created AI-enabled platforms such as Acquisio that can easily be used to manage marketing operations across various channels such as Google Adwords, Facebook, and Bing. This machine learning-enabled layer analyses the live campaign data with the help of sentiment analysis algorithms. Consequently, recommends the best distribution of marketing activities that will eventually yield to the greatest outcomes. This is because it automates regular bids and monitors overall marketing spend so that business owners can reduce the time spent on tracking marketing campaigns and pay attention to other important areas.

Another advantage of using AI base solutions is the ability for businesses to track competitors and review the competition on their busy schedules. For example, there are various competitive analysis tools such as Crayon that can be used to track competitors with the help of different media channels such as websites and social media. These platforms present the opportunities business owners with a competitive advantage of studying any changes in their competitors' marketing planning such as price changes, subtle message modifications, and public relation activities. In addition, small business owners may take the advantage of a large amount of online and offline information to make informed and data-driven decisions that can potentially grow their businesses. What is interesting about AI-powered tools for businesses is that they can be tailored into every data producing workflow, leading to the production of useful insights that are quite applicable and actionable. AI business tools such as "Monkey Learn" integrate and analyse data across various media channels, which then achieves timesaving analytics and create reports such as sentiment analysis in Google Sheets and CSV.

AI integrated customer support solutions such as automated chat systems permit small businesses to scale their customer service efforts and free up resources needed for more difficult customer interactions. Examples include AI customer services solutions such as Digital Genius and Chatty People that can suggest or automate answers to incoming customer questions, classify help tickets and direct inquiries or messages to the appropriate department. Consequently, by using this AI-inspired customer support, there is an enormous reduction in average handling time observed and an enhancement in the overall responsiveness of the customer service team. Lastly, AI has also improved Customer Relationship Management (CRM) in small-and-medium businesses through the valuable insights that help with managing interactions of present and prospective clients. These CRM platforms are embedded with AI functionality that can ensure real-time data analysis to provide predictions and recommendations based on businesses' unique processes and customer data.

Challenges and Forthcoming solutions

6.1 AI implementation challenges for socio-economic development and growth

The first challenge that African countries will need to overcome is the fact that computing is not that advanced. This is because Machine Learning and Deep Learning techniques that are the most beneficial for the advancement of AI require a series of calculations to be done very rapidly, and this can be in microseconds or nanoseconds. This, therefore, implies that that AI technologies utilise humongous processing power. The biggest debate amongst AI experts and policymakers has always been that there is insufficient processing power that is needed to capacitate and implement AI technologies. However, cloud computing and massively parallel processing systems have created hope for the implementation of AI in the short term. Nonetheless, as data volumes continue to increase, and Deep Learning advances towards automated creation of increasingly complex algorithms, cloud computing may become limited.

Creating trust in AI technologies because of security and privacy issues is another challenge for AI implementation. This is because numerous people perceive AI as a black box and difficult to understand. Consequently, people remain uncomfortable with AI adoption into the businesses and service providing outlets. For example, financial institutions such as banks prefer to utilise simple and linear mathematical algorithms that are easy to explain their input to output. Since AI applications need much more complex mathematical algorithms, numerous businesses avoid implementing them. Thus, since trust remains limited among people, it has been challenging to enable people grasp that this technology really works and possesses numerous opportunities for better accurate predictions. Furthermore, numerous people/businesses are concerned because of possible elevated complications due to governments overstep into their privacy. Hence, the enactment of legal and ethical regulations that can allow citizens to possess the right for explanations for governments' prying into their privacy and enable their contributions to the decisions that are made about them as a consequence of AI.

Another challenge that needs to be addressed is that most AI applications and deployments are vastly specialised. The specialised AI is known as applied AI. Applied AI is built such that it can perform tasks while learning in order to improve and become better at those tasks. In contrast, generalised AI is different such that it performs any task just as human beings. But all of these AI technologies are still to come in the near future. Moreover, these AI need to be proven that they can actually perform the tasks they are designed for. Currently, research institutions and AI-based organisations are still working on AI-based products that are yet to clearly demonstrate worth and achievements. As such, people remain doubtful on the methods that technology utilises in decision making and whether these decisions taken under different environment, more especially under duress, are accurate and precise. This is coupled by the fact that ultimately, the probability due to mathematical uncertainty behind AI predictions still remains uncertain for most AI applications. Consequently, it remains challenging to verify that the AI system's decision-making process is satisfactory.

Data privacy and security is another challenge as most of the AI applications are based on massive volumes of data to learn and make intelligent decisions. Machine learning systems hinge on data that is regularly sensitive and personal in nature. Since these systems learn from this sensitive data in order to improve themselves, there is a probability that these AI systems can

become prone to data breach and identity theft. Consequently, the European Union has implemented the General Data Protection Regulation (GDPR) that ensure the complete protection of personal data. This was a measure that was enacted after careful considerations based on increasing awareness and sceptics in AI end-users regarding an increasing number of machine-made decisions. Furthermore, there is a unique method known as Federated learning that is aimed at disrupting the AI paradigm and encourage data scientists to develop AI products and services without upsetting users' data security and confidentiality.

With respect to data scarcity, as much as more AI-based institutions have more access to huge data presently, datasets that can enable AI applications to learn are actually rare. However, there has been a rise of AI machines that are trained in supervised learning. But this kind of training requires labelled data. Labelled data is organised such that it becomes easier for AI machines to understand and learn. Nonetheless, the downside of labelled data is that it is limited and making future automated algorithms' creation increasingly more challenging to develop. However, the upside is the surge in investments towards design methodologies that focuses on how to create AI models that can learn, despite the scarcity of labelled data.

Generally, one of the major challenges of AI is that the accuracy of AI systems is dependent on the data on which the system is trained on. This means that an AI system is as good as the data it learns from. If the AI system is not trained sufficiently to generalise well enough, it can find patterns in the data that are inaccurate. A further challenge is that data required for training AI systems is not always available or in the required format.

AI techniques have proven to be effective in solving real-world problems. However, a number of these techniques, such as neural networks, are a black box output. For example, a prediction is produced without any explanation as to how the output has been arrived at. For example, management in industry or finance may not be willing to accept a prediction or reliability of the AI system without the justification of how the prediction was arrived at. Thus, the lack of transparency and interpretability is a significant drawback. Additionally, researchers are facing the problem of explanation already met in previous expert systems. However, a recent development in the field of AI, namely, explainable AI (XAI) aims to address this issue.

The widespread use of AI can be inhibited by the infrastructure and associated capital expenditure needed to set up and run such AI systems. For example, multicore and GPU hardware for machine learning techniques such as convolutional neural networks. Mechanisms need to be identified to provide the necessary infrastructure in Africa in order to promote the widespread use of AI needed in order to contribute to the economic growth of the continent. Even though AI has the potential for solving humanity's grand challenges in Africa, including accelerating the SDGs, Africa is still faced with a numeral of challenges towards the priority areas as described in the following sections.

6.2 Investment opportunities and challenges

The PricewaterhouseCoopers published a study showing the economic impact of artificial intelligence on the world's economy by 2030. The study showed that AI could improve global GDP by 14%, which was approximated at \$115.7 trillion. This could make AI the biggest commercial opportunity in the global economy. The report suggested that 2020 will be a tipping point for African's AI adoption as the report estimated that AI technology could also increase the GDP of Africa, Oceania, and other Asian markets by 5.6 %, which is about \$1.2 trillion (Figure 5). So, this stands to reason that Africa can reap significant economic rewards from AI technology. Nevertheless, the 2019 Government AI Readiness Index painted a predictably glum image for the African continent in global indices of this nature. Currently, there are no African countries in the top 50 positions of AI innovation. There are only 12 out of 54 African countries in the list that are in the top 100 of AI innovation and development. The top 5 placed African governments included Kenya, Tunisia, Mauritius, South Africa, and Ghana. The 5 countries reflected well-documented AI technology developments. Of the bottom 10 countries, 7 are classified as the Least Developed Countries.

In 2019, Kenya's ICT ministry set up a Distributed Ledgers Technology and AI taskforce to develop a roadmap for the transformative technologies that shall define 4IR. This Taskforce published arguably Africa's most comprehensive report and plan to date calling on the government to invest in blockchain and AI infrastructure and skills to combat corruption and implement educational and skills programmes for 4IR.

Africa's AI industry is still emerging when compared to USA, Europe, and Asia. However, this has not deterred some of the African continent's most innovative start-ups from developing solutions. This clearly proves the promising potential of AI-based technologies for Africa's economy. Since numerous African countries have a fledgeling AI startup scene, multiple pan African community-driven of public and private stakeholders to partner to improve capacity building and establish an enabling environment for growing the AI community across the region. For example, in a quest to consolidate AI-based success stories, an AI Expo Africa 2018 event was launched and has since become the defacto African data science challenge platform across the continent, with a community of more than 8000 African data scientists solving Africa 's toughest challenges through AI and other forms of technologies. Moreover, AI as a platform for good is now also coming to the fore in the region with one of the newest AI start-ups known as Enlabeler.

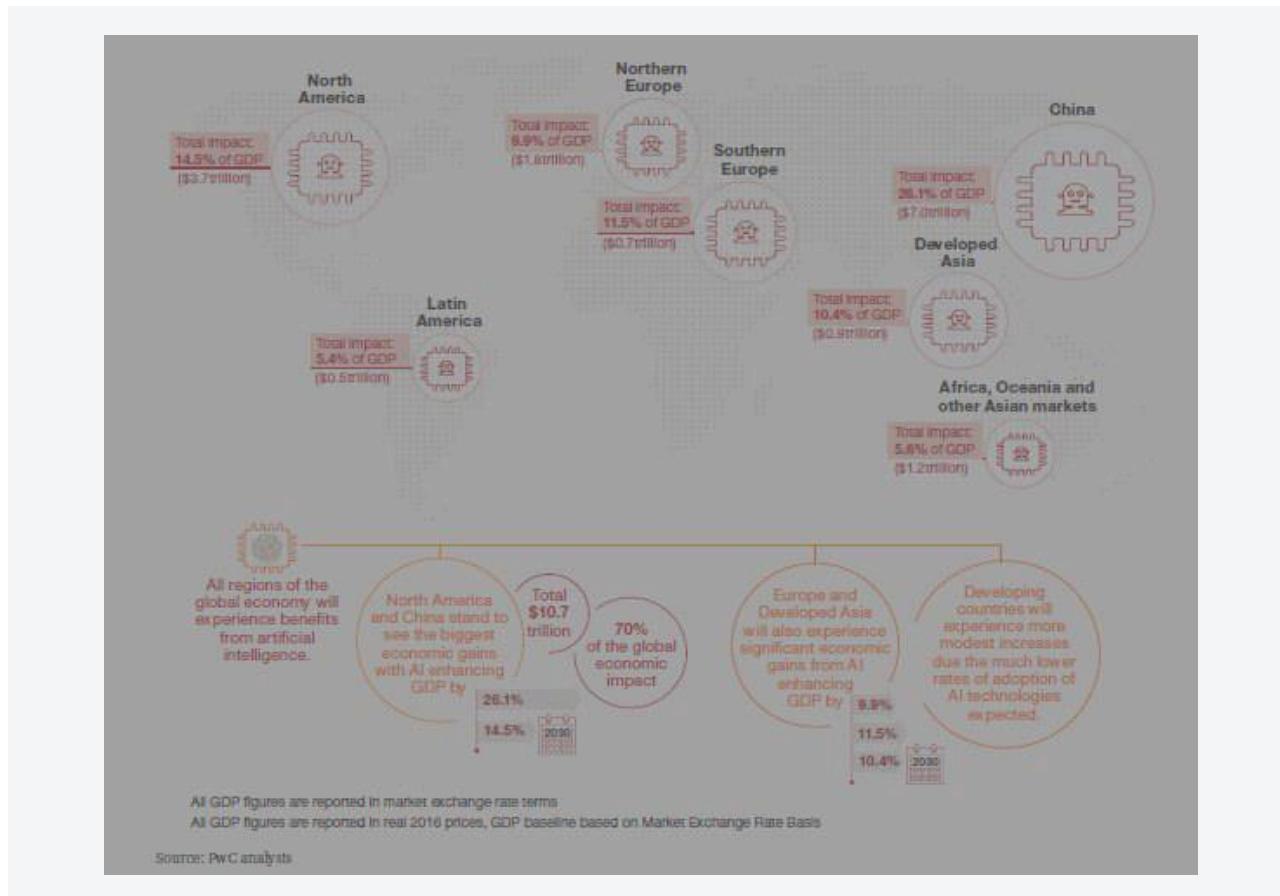


Figure 5: Projected GDP increases, and benefits generated from AI technologies around the world.

The Enlabeler platform creates jobs in South African townships and this data labelling industry is growing exponentially. This start-up has the mission of creating numerous jobs in South African townships and then scale its model to other African countries. More start-up companies are growing in African countries as shown in Figure 6. Most of these AI start-ups are found in South Africa, Kenya, Nigeria, Egypt, and Tunisia, with more than 5 start-up companies recorded. Countries with 2 to 4 AI start-up companies include Ghana, Uganda, Ethiopia, and Tanzania. Countries with at least 1 AI start-up company include Morocco, Senegal, Zambia, Zimbabwe, and Madagascar (Figure 6). Most of these AI are focusing on data and analytics as to the dominating innovative drive of AI business. This is followed by bots, chatbots, and virtual assistants. This is followed by vision, and then language known as text recognition. There are some hubs of AI centres also being established on the African continent. Health and diagnostics and professional services are the least pursued, indicating gaps and possible investment opportunities for upcoming start-up companies. Robotics is barely recorded, and this presents another opportunity of AI innovation for African businesses.



Figure 6: AI-based start-up companies in Africa adopting artificial intelligence-based

With respect to AI research showing gaps and challenges, Google has announced the opening of an AI research centre in Accra, Ghana. This is its first research centre in the African continent. This is following companies such as IBM that have opened research offices in Nairobi (Kenya) and Johannesburg (South Africa). Microsoft has also opened a data centre in South Africa and Amazon Web Services (AWS) is expected to open its own in 2020. Furthermore, much-established centres for AI R&D in South Africa are now being followed by Kenya and Nigeria who are ramping up investments in R&D. In addition, organisations such as Rwanda's African Institute for Mathematical Scientists (AIMS) are set to have a significant part in leading AI research on the continent. However, it has remained difficult to get a clear picture of the AI activities in Africa because most of the African innovators are excluded from global reports and events and lose on the opportunity to showcase African activity and innovations. This has led to global reporters claiming inaccessibility to information on AI activities in the African continent. For example, the Stanford Global AI Index and Europe's State of AI Report had minimal information on activity from Africa.

Thus, top African researchers should seek to attend global conferences to network with colleagues from other parts of the world and share their findings with the rest of the world. However, the challenge persists where most researchers are denied entry to countries where these conferences are held. For example, African researches innovators who attempted to attend the Neurips conference in Canada, for the second year, more than half the African researchers who applied to showcase their work were denied visas. This denial phenomenon systematically excludes African researchers from contributing to innovation at a global level.

It must be indicated that substantial investment in Africa is channeled towards technologies such as AI as shown in Figure 7 and Figure 8. The AI Impact Index is showing targeting and timing of investment into AI which is set to be the key source of transformation, disruption and competitive advantage in today's fast-changing economy. Drawing on the findings from the AI Impact Index, it was shown that sector-by-sector and product-by-product impact of AI will enable businesses to target opportunities, pinpoint threats and better address them. The unique analysis within the PwC's AI Impact Index includes the potential to free up time for consumers such as when utilising a driverless vehicle and enhance products and services quality and personalisation. Additionally, of cases analysed in this study, AI opportunities showed great potential for innovation, drivers, timings and high feasibility for AI adoption for markets globally. However, African countries still need to improve the odds of adoption by reducing barriers such as the absence of enabling environments, increased corruption, availability of capital investment to start-ups companies (Figure 7), accessibility to markets and more to overcome. The areas with the biggest potential and associated timelines need to be outlined for African countries at a high level to assist businesses to target investment in the short-to-medium term. For example, some aspects of change, such as robotic doctors, could be even more revolutionary but are further off.

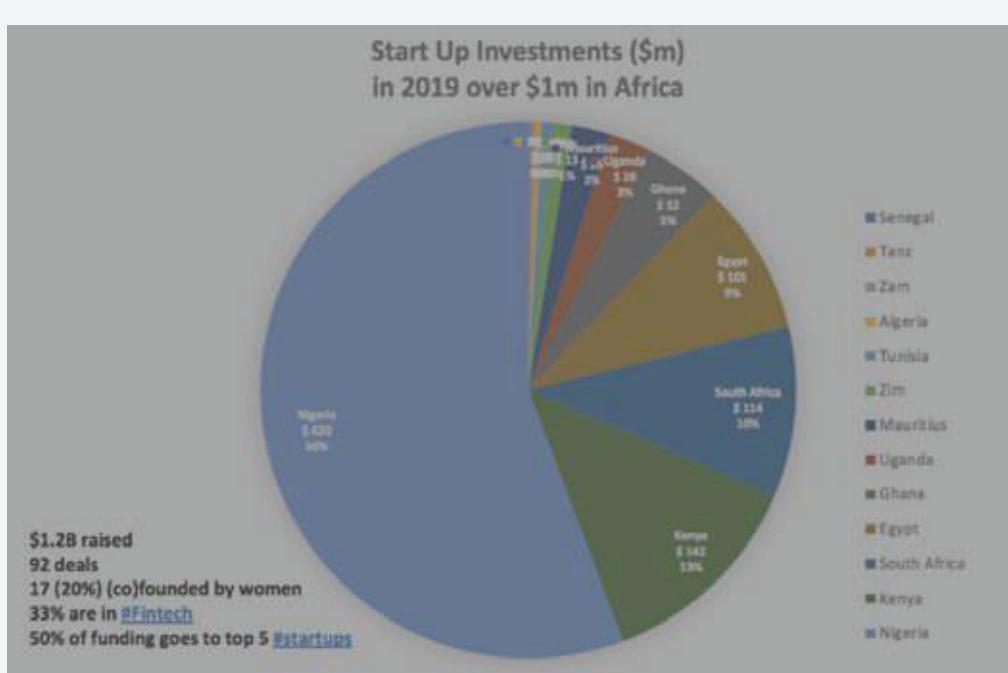


Figure 7: Start-up investment (\$M) in 2019 over \$1M in Africa

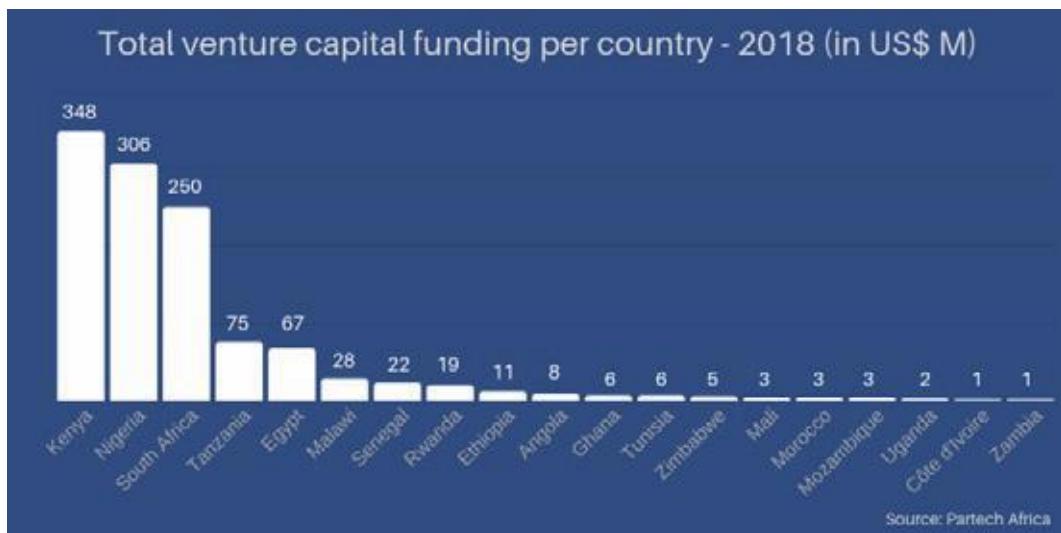


Figure 8: Total venture capital funding per country in 2018 (in US\$ M)

6.3 Conclusion

Notably, no sector or business will be immune from the impact of AI. In fact, the potential for innovation and differentiation could be all the greater because fewer market players are currently focusing on AI. The economic impact of AI on the world's economy by 2030 was shown to possess the potential to improve the global GDP by 14%, thus translating into approximated \$115.7 trillion. As this AI impact is presenting the biggest commercial opportunity in the global economy, African Member States need to take this opportunity for their citizens and the benefits of such will be determined by how Africa sought to harness from this lucrative AI venture. As 2020 has been suggested to be a tipping point for African's AI adoption, this is being observed by numerous African private and public institutions that have adopted numerous AI-inspired activities to conduct their day-to-day functions, during the COVID-19 lockdown. Continuing this trend could further increase the GDP of Africa, post-COVID-19 pandemic.

However, African countries ought to overcome the challenges that come with the implementation of AI to benefit from such ventures. For example, there have comparatively been limited organisations that have been interested in investing in AI-based products development. Additionally, there has been limited advocacy of AI towards existing businesses that could assist governments and businesses the benefits of implementing machine powered progress across the continent. Moreover, besides adopting AI-based technologies into their economic development, which is costly, retraining of the workforce to enable them to operate AI technologies need to be considered and financed. Therefore, increasing skills training in data science and incorporate AI technologies into the curriculum and offer platforms and tools will allow for AI-driven work to be offered as a service in AI-based economic development. Moreover, AI systems are designed from sensitive data to improve their functions, there is a probability that these AI systems can become prone to data breach and identity theft. Therefore, there is a need to create trust on AI technologies because of security and privacy issues are a cornerstone in AI implementation. This can be done through improved data privacy and security frameworks that will protect consumers.

There are numerous social-cultural, ethical and gender issues that have to be taken into account in the context of the advancement of AI technologies. These considerations fall into at least the following categories: educational and work challenges, the ethics of AI, legal challenges, and socio-cultural challenges. In this chapter, we will offer brief introductions to the problems associated

with these four types of constraints in the African context. However, it must be clear that there are many other sub-issues emanating from these challenges. The issues flagged here, are all issues needed for further research, policymaking, and

Africa remains faced with education and work challenges, namely, reformulating the future of work and considering the resulting implications for education and higher training. There are other related issues resulting from advances in AI technologies, such as the integration of AI into our everyday lives, concerns around AI and children, and the impact of social media on the quality of human interaction such as isolation, and bullying on social media, among others. These challenges fall in the domain of information ethics, smart cities and integrating AI into our homes via the Internet of Things. For example, this could possibly result in social exclusion and inequalities. This, therefore, means Africa should pay more attention to the issue of education and the future of work opportunities for the youth.

Ethics of AI falls into at least three main domains, namely data ethics, machine ethics and neuroethics. Data ethics are concerned with challenges emanating from bias and fairness, accountability, and transparency in machine learning. Machine ethics is concerned with two subfields, namely ethics of social robotics and the building of artificial agents. The ethics of social robotics entails a consideration of the design of social robots and how humans interact with such robots. For example, issues concerning dignity in the context of care robots. The fabrication of artificial moral agents is another consideration. This focuses on the prospects of creating computers and robots that can make explicit moral decisions. For example, lethal autonomous weapon systems. The third domain of neuroethics field is concerned with issues around the status of cyborgs and the mind uploading programme. The legal challenges focus on issues around responsibility when something goes wrong concerning AI applications. This entails the use of AI in the judiciary, privacy and property rights issues and governance of data as well as related issues around economic, social, and epistemic justice and robot rights. The focus here will be on the first three. Finally, some important socio-cultural concerns focused on gender equality in the advancement of AI technologies were considered.

Socio-cultural and Gender Considerations

7.1 Education and the future of work

The impacts of AI on education and the future of work were considered. It is evident that the nature of education and the structure of curricula for the schooling system has to be adapted towards AI technologies. The recommendation is that at the level of school education, the focus should be on intelligent networks and personalised educational systems. This can in-turn ensure lifelong learning, fairness, an increase in quality, and address the challenge associated with the lack of skilled teachers and related financial constraints in Africa. Thus, the curriculum should focus not only on new disciplines and skills, such as including coding but also on skills of social analysis. Social analysis can allow pupils to negotiate around the social and ethical impact of the AI.

With respect to the future of work and employability for young people, perhaps the most important skill set for successful future workers is adaptability. Africans must understand and accept that the world of work is going through the most encompassing transition than it had had to face in the past 200 years. Notably, the serious implication of this transition is that Africans must forget about ‘jobs’ and instead focus on ‘work.’ The fluidity that AI technologies and the developments AI brings implies significant disruptions at all levels, and distorting perceptions and expectations on how the world is known to have worked. Therefore, workers of the future must have the capacity to deal with the AI resultant disruptions and manage to constantly adapt to the changing circumstances and demands with respect to time-and-progress-sensitive skill sets.

There are non-negotiable moral responsibilities that governments must adhere to in terms of at least 5 main concerns and these are as follows:

- Ensuring that there is a shift in focus towards the quality of skills transferred to learners at school level. This should be such that the focus is on collaboration and teamwork, communication, critical thinking, and creative and innovative thinking skills. This skills transfer should enable learners to possess abilities such as complex problem-solving capabilities, financial and digital literacy, and presentation and marketing skills. These skills will ensure that learners and future workers are capable of critically reflecting on their cognitive abilities, adapting to circumstances, but remain creative;
- Revolutionise the nature of university curricula such that silo teaching of programmes/modules/courses is eliminated. This can be carried out such that the stringent separation of disciplines and faculties becomes obsolete. But there should be reorganisation and blending of disciplines and faculties across tertiary institutions;
- Focus on educational partnerships between purposeful businesses and universities;
- Funding research focused on finding optimal ways in which to re-skill and up-skill workers. This must take into account their unique existing skills set; and
- Making use of AI techniques to predict when re-skilling and up-skilling will become necessary.

7.2 Data Ethics: Fair, accountable and transparent machine learning

There is justifiably tangible excitement and enthusiasm about the potential of machine learning decision-making and predictive capabilities to benefit society. However, there are also serious concerns about the technology. For instance, there is a possibility of structural bias in algorithms derived for different AI applications. This can be in the form of stereotyping and unfair determinations that can be incorporated in machine learning applications such as voice-to-text technologies, facial recognition software, algorithms deployed to determine financial risk, and predictive justice tools. Given the nature of machine learning practices of latching on and learning via recognising patterns in data, there could be an inherent bias in data that may be amplified by, or at the very least, be transferred to resulting predictions and decisions.

This kind of bias opens the possibility of discrimination-by-proxy, however, unintentional this discrimination might be. Potential damages that emanate from machine learning practices include withholding economic, financial, and epistemic resources from certain social groups such as certain classes, nationalities, races, or genders, based on inherent identity prejudice in data. The identity prejudice includes members of certain races, or persons of a certain age or nationality or gender, which may end up not having access to home loans, and, even more serious, reinforcing existing prejudice via stereotyping, and under-representation. For example, speech-to-text software may not be equipped to recognise female voices, and facial recognition software may fail to recognise black female faces. Thus, there should be a culture of awareness of the impact of this kind of bias on society inherent to machine learning manifesting through their resultant decisions and predictions. Moreover, there is a recommendation that there must be agreements made between industry and government in order to ensure transparency and fairness in machine learning practices.

7.3 Machine Ethics: Social robots and the artificial moral agent project

A robot is an artificial entity that is situated in our world. We are faced with moral, social, political, and economic challenges with robots in our private, work, and social spaces. From being focused on the 3 D's (dull, dirty, and dangerous work), the field of robotics has exploded to focus on precision during surgery, NASA, military robots, and social interaction with care robots for the aged people, as well as nanny robots. Thus, the focus in this section was on robots in our social lives, as aspects of other robots are covered in other sections in the chapter and report in general. In terms of social robots, designed activities such as care, companionship and nanny robots, the following measures must be put in a place when the robots are deployed, through a policy enactment. The first measure is the definition of 'care' and 'companionship' should be made clear to ensure the well-being of humans interacting with these robots. Secondly, pointing out the limitations of these robots in terms of reciprocal social interaction is a necessity. And lastly, there should be some guideline of appropriate behaviour towards robots. Thus, the main point is to acknowledge the debate that exists on the benefits vs the risks of robot companions of all kinds. This means that, on one hand, there are concerns that the utilisation of care robots is unethical in terms of issues around human dignity, objectification, and shallowing of human social interaction. On the other hand, there is an acknowledgement of the immense potential for the improvement of the quality of life of the elderly and terminally ill via the use of care and companion robots.

The use of AI techniques in healthcare has huge benefits in biomedical research, diagnoses, treatment options and delivery, and many other aspects. However, the potential and ability of patients to adapt to changes in diagnostics and treatment as well as an emphasis on the responsibility of healthcare providers to maintain patients' dignity, confidentiality, safety, and privacy are imperative moral consequences of integrating AI techniques into health care practices. Thus, there are broader concerns with respect the ethical implications of social robotics include privacy issues, abuse of manufacturing of home and companion robots, and the potential impact of abuse on the moral fibre of society. Moreover, there is a possible negative impact on the quality of human social skills. Furthermore, integration with technology not only enhances human potential but also changes certain human characteristics. Consequently, we should not only ask about what will technology be like in the future but also what will humans be like in the future. This means, as a consequence of AI, what are humans becoming.

7.3.1 Moral Responsibility

The moral responsibility brings us into the domain of the artificial moral agent, which seeks to find out how much of humans can be transferable to AI. The complexity of the artificial agents that are being built such as autonomous weapons systems, autopilots, and expert medical ethics systems, emphasises the urgent need of discussing the moral capabilities of such agents and managing their potential risk. To have such a discussion, we need to consider the best responses to the following questions:

- What are artificial moral standards?
- What is an artificial moral agency?
- What is artificial moral responsibility?
- What is the moral status of an AMA? and
- What is moral personhood, moral rights, etc.?

An agent has moral agency and full moral status if they can control and reflect on their behaviour. This is done by considering the harm and/or good of their actions by adhering to some ethical system. When we consider what the conditions for the artificial moral agency could be, there are many suggestions that can be made. These suggestions include the following, and different combinations of the following: free will, consciousness, responsibility, intentionality, autonomy, interacting ability, adaptability, and ability to engage in moral reasoning, among others. Thus, it becomes obvious that, given the different levels of autonomy of the agents we are building, we should consider instating levels of moral status relating to that autonomy. Different writers suggest different levels of moral status. However, the agreement is that while artificial moral agents cannot have full moral status and moral agency yet, they must have some kind of dynamic or functional morality. This brings us to the question of moral responsibility, which is, would AMA's be morally responsible? Do we think of their actions in terms of praise or blame? There are various additional issues to consider here, but the most important is perhaps how do we ensure the values that are considered as part of the ethical framework for building these agents agree with our values in Africa, and not just with Western ethical systems?

7.4 Legal challenges

- There are basically three kinds of concern pertaining to legal aspects of AI applications and these are:
- Can we hold AMA's responsible for their actions? Why, or why not? Do we think of the actions of an autopilot in terms of responsibility in the same way that we do of an automated vacuum cleaner or following the directions on Google maps? Should we? Why, or why not?
- How do we ascribe moral responsibility to an agent that does not have full moral status and agency? Should we? Why, or why not? and
- How do we close or minimise the responsibility gap? Who is responsible in the trajectory from manufacturers to programmers to users to the software itself? Is there a one-size-fits-all answer to this question, or do different applications have different responses?

7.4.1 The Use of AI in the Judiciary and Predictive Justice

This issue of AI in the judiciary and predictive justice firstly relates to the problems generated by AI techniques making possible the creation of 'false' evidence. Thus, creating some form of 'evidence dilemma.' For example, fake news, fake videos, and more can be generated through AI. The second issue relates to the use of AI in legal practice. This can be using machine learning algorithms to make predictions about bail, analyse evidence and decision-making. Furthermore, some of the most important points to consider here determine if the use of AI in the justice system must always be compatible with human rights. Moreover, AI users must ensure that the techniques used do not contribute to any kind of discrimination. Furthermore, it should be

ascertained that the responsibility to be fair and transparent when the processes of machine learning practices are used in the judiciary and properly explained. In addition, the related responsibility must be to ensure that data and models, as well as evidence, are of the best quality and that cyber safety is a high priority. Future concerns include considering whether robots have rights, or whether they can be slaves, and whether it even makes sense to speak of robots being mistreated.

There are numerous issues around privacy and confidentiality that accompany the integration of AI techniques into our social, economic, and personal lives. These issues include healthcare, education, and finance. Property rights and privacy rights intersect in this 4IR context in fascinating ways. Specifically, there are two areas that need to be flagged and taken note of for the social and secure good of Africa. Firstly, there is the issue of ownership of data. One's own data may become one of the most valuable commodities of the future. This then heightens the need for privacy laws and the need to ensure the public become literate with AI fundamentals. Secondly, intersecting with this one is whether AI is a private or social good. Responses to this question will impact on how moral responsibility issues are viewed and guide the nature of approaches towards policy and regulatory initiatives.

7.5 Gender consideration

AI and deep learning are taking an increasing place in the daily and professional lives of people, not without exacerbating gender gaps. It is not a question of apprehension or cleavage linked to the capacity of women to create, develop, innovate, and disseminate knowledge pertaining to AI. But AI is not different from other scientific fields. It is based on observed data that it may possibly reinforce gender inequality and social bias, more especially in the African continent. The reasons the gender gap may develop are two-fold; the wider gender gap in AI technologies, as well as the undergoing risks associated with AI applications and systems unsuited towards Africans' social and cultural contexts.

Gender unsteadiness exists within the science, technology, engineering, and mathematics (STEM) fields, across the world. It has been reported that in scientific research, women represent less than 30% of global researchers. Moreover, women are less than 22% in AI-related fields. In addition, this gap appears more visible for researchers from French-speaking countries than English-speaking countries. According to the "Global Gender Gap Report 2020" and "The AI Index 2019", there is limited studies available about such gender gaps in the African continent. With regards to STEM gender issues, segregation has been observed between males and females to be more significant within Sub-Saharan countries such as Mozambique, Lesotho, Ghana, and Ethiopia. South-Africa is the only country listed in the AI-Index-2019, and the proportion of female professors working in AI space are 28%, thus exceeding the global world average of 20%. Consequently, this imbalance will draw drastic consequences on the job market. It will also have an influence on AI systems in the everyday life of African citizens. Thus, to ensure that these technologies do not contribute to the increasing social and economic inequalities, general mobilisation is thus necessary. For example, African researchers, more especially women, must be encouraged and supported to contribute to the design and the incorporation of local sensibilities, data, and knowledge in AI applications to avoid racial discrimination and bias values.

It has also been predicted that the job market will be significantly impacted by AI. AI will have a negative impact on many digital applications that are susceptible to automation, more especially in industry. This is because AI may accelerate labour substitution. For example, clerical jobs and bank tellers' jobs that are currently and predominantly held by women are at high risk of elimination. This will be due to the introduction of intelligent software in computer vision, image analysis, natural languages understanding and processing, and proliferation of online chatbots. Hence, African women are at the forefront of the struggle to preserve Africa's varied cultures, languages, and identities to fully harness the deployment of AI. Moreover, intelligent automation engine is coming with women's voices, namely Eliza, Alexa, Cortana, and Siri. However, the accents and names of these digital voices are foreign to the African environment and exacerbating the existing gender divides because it's presenting women as better in these secondary roles. Even though it is difficult to predict the future, but national governments and African scientific institutions have the responsibility to address the scarcity of women in AI and invest more on sustainable development.

7.6 Conclusion

For the advancement of AI technologies, numerous social-cultural, ethical and gender issues must be considered. The educational and work considerations must address the ethics of AI, legal challenges, and the accompanying socio-cultural challenges. These flagged issues for a better adaptation of AI need further research, policymaking, and legislation among African Member States. For example, for Africa to better support education and work framework systems, there is a need to reformulate the resulting implications of primary, secondary and tertiary exposure, and training. There are considerations such as the integration of AI into our everyday lives with regards to children. For example, there is need to monitor and evaluate the impact of social media on the quality of human interaction such as isolation and bullying on social media. Moreover, social exclusion and inequalities could arise because of the domain of information ethics, where smart cities integrate AI into the inhabitants' homes via the Internet of Things. Therefore, Africa should focus on education and the future of work opportunities for the youth, more especially women and girls. Gender unsteadiness within STEM fields has been reported to show that less than 30% of women in the global scientific research community. Furthermore, women are less than 22% in AI-related fields, more especially among researchers from French-speaking countries than English-speaking countries. Thus, African countries need to bridge or address these STEM gender gaps issues. This imbalance will draw drastic consequences on the job market if it remains unaddressed.

This chapter describes the need for research of AI in Africa and what should inform the nature of research conducted therein by a nation or region. It also establishes that the ordinary people and government officials should be able to understand, appreciate and apply the results of research problems in AI. Not only must Africa increase its human capacity in the field of AI in order to innovate, but it must also conduct studies in pedagogy. AI pedagogy can introduce the concept of AI unto children and enable a seamless way of living. For emphasis, examples of national AI strategies across the globe are provided to illustrate the seriousness with which several developed and developing nations have taken this challenge.

Research, development, and innovation

8.1 Possible explanations for the slow progress of AI research

Since the launch of AI research in 1956, the growth of this field has slowed down over time and has stalled the aims of creating machines skilled with intelligent action at the human level. A possible explanation for this delay is that computers lack a sufficient scope of memory or processing power. In addition, the level of complexity that connects to the process of AI research may also limit the progress of AI research. While most AI researchers believe strong AI can be achieved in the future, there are some individuals such as Hubert Dreyfus and Roger Penrose who deny the possibility of achieving strong AI. On the other hand, John McCarthy was one of the various computer scientists who believe human-level AI will be accomplished, but a date cannot accurately be predicted. In addition, conceptual limitations are another possible reason for the slowness in AI research. AI researchers may need to modify the conceptual framework of their discipline in order to provide a stronger base and contribution to the quest of achieving strong AI. As William Clocksin wrote in 2003: “the framework starts from Weizenbaum’s observation that intelligence manifests itself only relative to specific social and cultural contexts”. Furthermore, AI researchers have been able to create computers that can perform jobs that are complicated for people to do, such as mathematics. But conversely, they have struggled to develop a computer that is capable of carrying out tasks that are simple for humans to do, such as walking known as the Moravec’s paradox. A problem described by David Gelernter is that some people assume thinking and reasoning are equivalent. However, the idea of whether thoughts and the creator of those thoughts are isolated individually has intrigued AI researchers.

Clocksin says that a conceptual limitation that may impede the progress of AI research is that people may be using the wrong techniques for computer programs and implementation of equipment. When AI researchers first began to aim for the goal of artificial intelligence, the main interest was human reasoning. Researchers hoped to establish computational models of human knowledge through reasoning and to find out how to design a computer with a specific cognitive task. The practice of abstraction, which people tend to redefine when working with a particular context in research, provides researchers with a concentration on just a few concepts. The most productive use of abstraction in AI research comes from planning and problem-solving. Although the aim is to increase the speed of computation, the role of abstraction has posed questions about the involvement of abstraction operators (Gelernter, 1994).

Another possible reason for the slowness in AI relates to the acknowledgement by many AI researchers that heuristics is a section that contains a significant breach between computer performance and human performance. The specific functions that are programmed to a computer may be able to account for many of the requirements that allow it to match human intelligence. These explanations are not necessarily guaranteed to be the fundamental causes of the delay in achieving strong AI, but they are widely agreed by numerous researchers. In addition, there have been many AI researchers that debate over the idea of whether machines should be created with emotions. There are no emotions in typical models of AI and some researchers say programming emotions into machines allows them to have a mind of their own. Emotion sums up the experiences of humans because it allows them to remember those experiences. David Gelernter writes, “No computer will be creative unless it can simulate all the nuances of human emotion.” This concern about emotion has posed problems for AI researchers and it connects to the concept of strong AI as its research progresses into the future.

8.2 The case for cutting edge in AI research

Such application areas include synthetic music, telemedicine, and precision surgery as well as smart telescopes that auto-detect and analyse pattern changes. In everyday life, advancement in AI fields of image and speech recognition, and more are being integrated into computers, televisions, and mobile devices. All such advances are made possible by the increased funding in the educational, industrial, and military research. Traditionally, the USA has primarily been at the forefront of AI research and applications that have led to significant AI strides (Figure 9). However, China is posing a challenge to this dominance. Nevertheless, Africa must also step up her efforts in AI investments in research, application, and innovation, as there has been meagre funding into AI within the continent. To determine the appropriate AI branch credible for investment, it would be useful for each nation to examine the available resources it possesses and the needs it aims to address. Thus, policymakers ought to first consult widely and conduct a survey within their populace, industry, and academia with regards to AI advancements and resultant effects. The survey data obtained should then be utilised into formulating a decision problem that can be solved via risk analysis.



Figure 9: Top global literary research output in AI in recent times image source: Elsevier AI resource centre

Figure 9 shows the top global literary research output in AI in recent times. Africa, India, and South America and more have a combined 29% contribution towards AI innovation, compared to similar quantum from China, USA, and Europe. However, it is plausible that some of the articles and products from the leading regions in AI have input from people of African origin. It is a fact that Africans in the diaspora are very productive due to the conducive environment they operate within those developed economies. For example, Dr Stephen Odaibo, a medical doctor by profession, is the CEO and Founder of RETINA-AI, USA. His firm developed and released the first AI mobile application for eye care providers. The application known as Fluid Intelligence reportedly detects macula oedema and sub-retinal fluid on Optical Coherence Tomography (OCT) retinal scans with over 90% accuracy. Within the African continent, Dr Jacques Ludik, the Founder and President of Cortex Logic in South Africa, is a pioneer investor and AI expert in data analytics. This company provides an AI Engine for Business to solve strategic and operational problems. Likewise, Dr Tunde Adegbola is founder of African Languages Technology Initiative in Nigeria. He partnered with Microsoft to localise Microsoft Windows and Office to Hausa, Igbo, and Yoruba, which are the 3 widely spoken Nigerian languages (Adekanmbi, 2019).

Thus, to advance AI innovation in Africa, African firms and researchers need encouragement via local patronage, policy/regulation, and funding support, among others. Thus, event organisations such as the Demo Africa event has been established to showcase innovation across the technology industry within the African continent. For example, in 2018, Demo Africa focused on featuring new AI products offered by African start-up companies (DEMO Africa, 2018).

Unfortunately, as previously noted, most of the notable educational along with commercial efforts in Africa are led and mostly sponsored by foreign companies such as Google AI Laboratory in Ghana, Microsoft in Kenya, Zipline in Rwanda, and more (Cisse,2018; BBC News, 2019). But at the same time, Africa must compete in being able to conduct cutting-edge research in AI and have the support to convert successful research projects into products and services used by citizens. AI research is socio-technical in approach, cross-disciplinary in scope and collaborative in engagement. On the research side, this means having resources available to have cutting edge researchers as well as avail them to mentor the next generation is imperative. Thus, support for research, development, and innovation (RDI) must be sizeable in order to be able to:

- Develop, attract, and retain top talent;
- Acquire and develop the required technical resources such as computing, data gathering, and policy updates; and
- Prepare and transfer innovations into the market.

As the International Labour Organisation (ILO) prepares for the “future of work,” it recognises that jobs and workers will be greatly impacted by robotics and AI (ILO, 2020). Therefore, Africa cannot afford to be left behind in AI; there is no excuse not to engage in relevant RDI.

8.3 AI research and indigenisation

Africa’s strength must be looking at her local context for innovative inspiration and utilise such localised innovation to affect global reach. Research direction should include:

- Applied research adaptively utilising relevant existing AI tools and techniques, to provide home-grown African solutions to African problems particularly in agriculture, education, health and commerce. The identified sectors are crucial to our continued survival as a people and pertinent to African culture historically;
- Fundamental research into evolving African-value-driven theories and metaphors that enable contextualisation and indigenisation of fundamental paradigm and principles, governing the field of AI; and
- A socio-technical methodological framework for social management of AI technologies.

African researchers need to have mobility across countries to enable collaboration and cooperation. Thus, this can improve the free flow of ideas while encouraging more intra-Africa collaboration. Sharing of resources is also important in allowing those researchers with resources to afford access to researchers who might still be building up. Additionally, the continent needs domain experts that can investigate new solutions to the challenges facing our society, businesses, and governments. Hence, establishing research networks, professorships and resourcing for young faculty is vital. Furthermore, private sector companies need to invest in R&D to advance innovation. Given the high-tech needs for AI proficiency, the industry must collaborate with academia and other research laboratories emerging across the continent. Moreover, businesses should also realise their role in training the next generation of researchers, scientists, and engineers. They must further support AI by directing sizeable corporate social responsibility (CSR) towards junior educational schools for the promotion of science and technology. This can be achieved through the provision of industrial tours for pupils so to stimulate their interest STIs and the donation of computing laboratories resources. It can also be through the sponsorships of scholarships and bursaries, innovation challenges and quiz competitions.

Notably, the post-COVID-19 world will depend a lot on remote-work aside adoption of AI-driven and virtual technologies. Failure to be involved in the creation and hosting of web-based services would thus pose significant national security risks. More than ever, Africa should now begin to utilise its natural resources for the local production of mechatronic components and devices. Presently, there is a race by numerous nations seeking to swiftly produce low cost, efficient and possibly ‘smart’ ventilators during this coronavirus pandemic. Some producers are even placing restrictions on the export of drugs such as chloroquine. Therefore, this is clearly demonstrating that Africa cannot always count on importation. Thus, the development of national capacity for automation and intelligent manufacturing is now imperative.

8.4 Resource, resource, resource

To make Africa’s presence felt on the global stage, Africa needs to have a sizeable investment in AI R&D. African Member States should seek partners across territories and continents in order to build research investment and resources. Moreover, Africa needs to be able to produce bachelors, masters and doctoral degrees in STIs that are with AI aligned programmes. Thus, for Africa to achieve these ambitions, African institutions will require sharing of mentorship and resources. This could be in the form of specialised programmes that are accessible in different countries. For example, there are several programmes being formed for such an ambition such as the African Master in Machine Intelligence found in Kigali, Rwanda. Similar programmes are also available in countries such as South Africa and Morocco. Based on the success and effectiveness of such interventions, similar programmes could be scaled up and established across the African continent.

There is also a need to develop, not only expertise in AI but also indigenous datasets. This should be carried out to model and solve our peculiar African problems. Thus, data must be collected, collated, stored securely, and used for our benefit of the African land. Several aspects of AI are more software-driven and simply needs our intellect, and few computing resources to jumpstart. Additionally, there is the advantage of accessing open-source systems, online collaborative forums, and more for rapid development. Therefore, the continent could play a greater role and consequently benefit more from this technology.

8.5 Government must enter the game

Governments across the continent have a significant role to play in RDI that is more than simply resourcing, policy and funding. Governments can also largely procure AI technology so that they can deliver public services to their citizens much more effectively. It is thus imperative that RDI becomes part of the way government interacts with AI. This can be through providing opportunities for local companies and researchers to enable them to test and deploy AI solutions that are excellent, thoughtful, and respectful to the local context.

Across the globe, numerous countries have adopted various strategies that they have employed to promote RDI in AI with purposeful strategies and policies. For example, Canada provides funding for start-ups and encourages immigration of experts. On the other hand, China promotes early adoption and massive economies of scale. The United Kingdom promotes data sharing and partnerships with global companies. In April 2018, the EU Commission adopted the communication on AI where it aims to increase the EU’s technological and industrial capacity and AI uptake by the public and private sectors. It is also to prepare Europeans for the subsequent socioeconomic changes (Dutton, 2018). Thus, the African countries should amongst other things do the following:

- Have short and long-term goals and investments in AI research; Envisage and
- address the ethical, legal, and societal implications of AI; Develop shared
- public datasets and environments for AI training and testing; and ensure the
- safety and security of AI systems.

However, Africa must first address the fundamentals by improving Internet penetration, electricity and power accessibility to communities and ICT governance.

8.6 Conclusion

Research, development, and innovation neither happen nor succeed by chance. It is the result of well-articulated and pursued efforts. African governments at all levels need to be inspired by the AU to deliberately invest in AI research and utilisation. Governments across the continent have a significant role to play in RDI that is more than simply resourcing, policy and funding. Governments can also largely procure AI technology so that they can deliver public services to their citizens much more effectively. Europe, North America as well as Asian countries have marshalled development plans in similar direction years ago. There is a need to build capacity in Africa in this emerging technology and steer it to areas of competitive national advantage. Thus, Africa must step up her efforts in AI investments in research, application, and innovation. In addition, each African nation needs to determine the appropriate AI branch credible for investment and determine the available resources it possesses for investment purposes and the needs it aims to address. Cooperation and consultation efforts need to be increased between policymakers, the industry, academia, non-governmental organisations and the general public on AI advancements and resultant effects. The survey data obtained through this consultation can then be utilised into formulating decisions based on risk analysis.

Youth and skill development for the African continent are intricately connected. Africa is the youngest continent, and this presents an opportunity for exploiting this demographic dividend. African countries must be able to meet the socio-economic needs of the youth as a path to their prosperity. AI is one of the areas where this is very feasible. Young people are not waiting for established industry and governments to lead them in developing their skills in artificial intelligence, machine learning and data science. Young people have been self-organising around the continent and finding ways to teach themselves and each other these skills.

Youth, skills, and capacity development

9.1 Youth are already moving

Amongst the youth populace, there is a hunger to learn AI, not simply for the sake of it, but to be able to push its limits and contribute to the cutting edge. Examples such as the Deep Learning Indaba, Data Science Africa, Data Science Nigeria, Codefest Nigeria, Runmila AI Institute have worked to bolster Africa's development in AI and machine learning. These platforms are mostly made up of young researchers and youth from numerous African countries. In places such as Nairobi, Kenya, a bustling community of young AI and data science enthusiasts meet regularly on weekends to learn and teach each other. After-which, the youth take their skills back into their companies or utilise the newly acquired skills towards their studies, and some towards building new AI-based enterprises. This type of learning is agile, but at the same time requires that we recognise its importance in creating enthusiasm in AI across the board. At universities, such as the University of Pretoria (South Africa) and the University of Lagos (Nigeria), AI student societies have sprung up. These developments point out that skill development is driven by energy from the bottom up.

9.2 Skills development from the bottom up

AI skills need to be grown across the African continent. This means that Africans should move away from simply being consumers of AI technologies, but creators and knowledgeable users. In the latter point, African countries need to have their societies understand how the technologies work in general and what effects they have on society. Without this, we as Africans will not be able to interact with these AI technologies in our own terms based on our African values.

African countries must start AI education and skill-building much earlier in children lives. When children are in school, they should be taught computing (including AI) in such a way that they can understand its ubiquity in their lives as well as become smarter users and developers. This challenge is not just in AI, but there is also a scarcity of digital, mathematical and data skills across the African continent. Thus, African countries must reintroduce these skills to formal education systems, as well as those individuals already in employment. As these skills continue to be grown, there is a need for formal programmes in computing, AI, data science and ethics of AI. These will be undergraduate programmes all the way to doctoral training. Moreover, the youth must be made aware of the research pipeline opportunities available with respect to AI-related fields. Furthermore, it should not simply be about the youth acting as support for outside technologies but being able to shape AI technology to suit the African context. These skills will prepare African youth for the next generation of work and reduce some of the social effects African may face as AI disruption marches on.

9.3 Many outcomes, not just degrees

The skills pipeline should lead to multiple outcomes and outputs. Some participants will end up in the industry, as entrepreneurs and in government as policymakers and implementors. Some participants should end up in centres of excellence in AI aligned programmes around the African continent. Earlier, it was mentioned that MS programmes in AI/DS in different countries could be the beginning of Centres of Excellence, which can then move onto having parts of these cohorts enter doctoral programmes. Furthermore, African countries should establish robust resources that can assist graduates in establishing careers across the continent, to prevent brain drain. Moreover, African governments should utilise good mentorship networks

and create opportunities. This should be carried out to learn and use advanced skills to tackle some of our societies' local challenges and be rewarded for such opportunities.

Africa's capacity is infinite given the youth populace. However, building capability for Africans should be considered as a long-term goal. Which is why short-term thinking will not assist the African continent's socio-economic growth with respect to AI technology. African governments must look at a phased approach in building up skills, leading up to a new computationally driven capability that is agile to changes that will eventually come. Furthermore, African countries will have to choose specific opportunities within AI that they will focus on. After measured growth and training in those AI fields, these African countries will be able to offer services and products related to those fields to other countries in a cooperative manner.

9.4 Representation and inclusiveness

More Africans are needed to play a significant role in the AI/ML space. This is particularly important in that as African governments and businesses are building skills, those interested must be encouraged to have enough curiosity to persistently learn, even though they face challenges and failure until they achieve tangible outcomes and outputs. In this way, such innovators can increase the representation of Africans in building and shaping the AI technologies. This will not only result in better products but address the biases that are already inherent within AI/ML systems' adoption and adaptation.

9.5 Capacity development of AI across the African continent

The African continent cannot afford to abstain from the race of AI adoption in order to create a competitive advantage in her socio-economic development and accelerate progress for national security and well-being. Many developed and developing countries are preparing new generations of professionals with technical skills that will master the different methods of AI. This workforce will also be aware of the ethical and symbolic challenges that AI represents. The massive processing of data generated by connected devices creates new professions such as data scientists, AI programmers, and more. This will allow for considerable progress to be made, in particular, by the massive collection of data leading to data analytics. This progress will increase computing capacities and advances in algorithms. If deep learning seems to be preponderant, the other sub-domains such as robotics, computer vision, automated reasoning, machine perception, augmented reality and knowledge representation will also advance over time and catch up.

Currently, it remains challenging to predict all the technological advances that will be realised as a result of AI. But there is an urgency within African Member States in engaging on training programmes for public and private institutions in launching licences and developing robust undergraduate and post-graduate (masters and PhD) studies which can match up to the rapid emergence and deployment of AI technologies. An AI descriptive bibliometric study of scientific papers on research trend in African countries covering the period up to 2020, indicates feeble participation of African countries towards AI research, development, and industrialisation. This mapping is based on the web of science databases and concern exclusively AI high ranked journal publications.

The continent is divided into three categories as shown in Figure 10. As shown, there are significant disparities within the African countries. For example, there are only five (5) African countries with more than 1500 publications. Of those countries, only one

(1) country has 127 publications. The rest of the other countries possess zero publications on AI-based technologies. It was also observed that some universities in selected African countries have competitive training programmes with high standards, comparatively speaking. Furthermore, lack of employment, and research and development opportunities, as well as funding in national companies promotes a brain drain from the African continent. The disparity and situation remain critical and fraught

with the African context. Hence, this report on the AI-powered future in Africa is of utmost importance and urgent. Therefore, the academic community, policymakers and scientific corporations have an important role to address the opportunities and challenges presented by AI.

9.6 Qualifications, reskilling, and employability

In the 4th industrial revolution, AI has become interdisciplinary in that it features into various facets of socio-economic challenges of Africa including health, finance, agriculture, and manufacturing. Thus, African universities should ascertain that the qualifications currently offered, more especially Computer Science degrees, can sufficiently equip African graduates with the skills necessary to meet the challenges posed by the 4th industrial revolution incorporating AI. Therefore, a review of curricula at universities, together with input from industrial and relevant sectors, should be conducted to determine whether curricula include the relevant building blocks that can sufficiently equip graduates for their particular careers in the 4th industrial revolution.

There is also a skills gap within the current workforce that will need to be bridged to provide people with the necessary skills to deal with new challenges arising in their jobs changes as a result of AI. African countries need to identify these affected sectors of the workforce. This will be necessary depending on the infrastructure of that particular country and may require to put in place mechanisms, such as short courses and certification, to provide the necessary support needed to upgrade skills of its citizens and workforce.

One of the growing concerns emanating from the incremental role that AI is playing is the loss of jobs. In several sectors, AI will complement jobs, helping to reduce workload and worker fatigue. However, there will also be a skills shift that will result in certain jobs becoming redundant, but new jobs arising. The skills shift needs to be managed to reduce unemployment resulting from this development. In addition, planning needs to be done with industry and the various sectors. This can be carried out by firstly identifying what the skills shift will be and which parts of the workforce will be affected by this advancement. After identifying these gaps, public and private institutions may need to provide timeous training. This training will equip the workforce with the necessary skills needed to move into the new jobs brought about by AI and 4IR.

9.7 Conclusion

African must focus on youth and skill development as they are intricately connected. Since Africa has a young population, African countries have the opportunity to exploit this demographic dividend. This will improve the chances of African countries into being able to meet the socio-economic needs of their citizens and present a path to prosperity. Thus, AI makes this ambition feasible. African countries should build on the enthusiasm and exploit that young people are already establishing themselves in developing artificial intelligence, machine learning and data science. There is tremendous enthusiasm from young people self-organising around the continent in finding ways to practise and learn AI-based skills. Moreover, Africans should be creators and knowledgeable AI users and avoid being just consumers of AI technologies. Additionally, African countries must start AI education and skill- building much earlier in children lives. When children are in school, they should be taught computing (including AI) in such a way that they can understand its ubiquity in their lives as well as become smarter users and developers. This challenge is not just in AI, but there is also a scarcity of digital, mathematical and data skills across the African continent. Thus, African countries must reintroduce these skills to formal education systems, as well as those individuals already in employment.

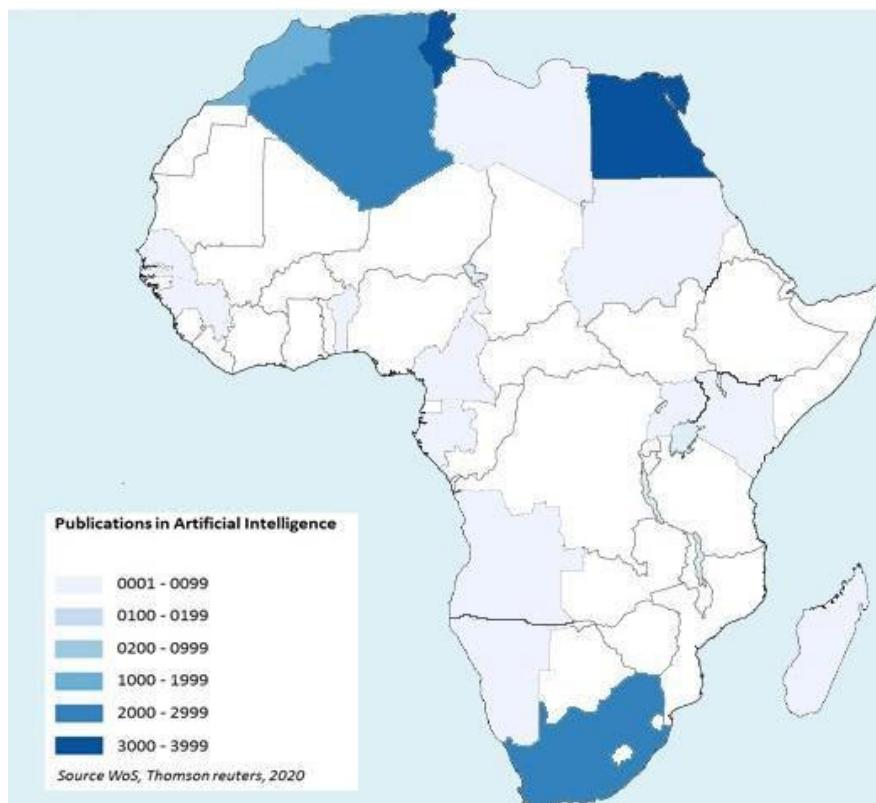


Figure 10: Publications in Artificial Intelligence

The government of any African Member State is a key role player in the development of policies, rules and regulations related to AI. Through the national agenda and vision setting, the government sets the tone for the country's development trajectory. Therefore, this informs the formulation and implementation of the policy. In addition to setting and implementing policy, the establishment of the national infrastructure required to support and facilitate the development of AI requires sanctioning and leadership of each African Member State. In playing this leadership role, the national governments have the obligation of ensuring that AI policy and practices are co-created with other role players such as the private sector, academia, and civil society. Thus, each country should formulate a clear and cohesive national in-country strategy for AI. This national strategy should constitute appropriate indicators that can be utilised to track progress, and iteratively assess the success and impact of policy interventions. Depending on their current level of AI readiness and availability of resources, the strategy should include the following:

- Establishment of a national AI infrastructure;
- Promote AI awareness, education, and research;
- Develop AI tools, standards, and platforms;
- Design policy and regulatory interventions for AI;
- Allocate specific resources for national AI initiatives;
- and establish and affiliate with an AU institute for AI to coordinate and support national AI strategy, resources, and initiatives.

Recommendations for AI Adoption and Implementation

10.1 National AI infrastructure

An AI strategy should set a clear and shared vision for each African country. A national AI infrastructure can be established to support, coordinate and drive this vision. This could include AI forums, societies, networks, and institutes. One approach is the establishment of a national institute for AI to facilitate AI skills and policy development in order to coordinate a national AI innovation ecosystem. An example of such an institute is the Centre for AI Research (CAIR) in South Africa. The CAIR is a national research network that conducts foundational, directed, and applied research into various aspects of AI, including AI for Development and Innovation and AI for Cybersecurity.

10.2 AI awareness, education, and research

There should be a drive to improve AI literacy and awareness for the African populace. For example, there is often confusion between the terms AI, machine learning and data science. AI is a broad area that includes machine learning and much of data science and analytics (see Chapter 4). An example of such an initiative will be to impart basic coding to all learners starting as early as primary school. Hence, emphasis must be placed on ensuring that these training, awareness, and education initiatives are focused on demographic communities that are usually under-represented in technology development. These under-represented demographic communities include women and the handicapped population, in order to address the ethical concerns around bias often associated with AI.

At universities, AI is usually taught to undergraduate pursuing computer science, and sometimes computer engineering bachelor's degrees. Therefore, these departments must be strengthened in order to be able to keep track of the rapid research advances being made in this area. As the custodians of AI, computer science departments will maintain advanced expertise in AI. They need to rapidly update curricula so that the computer science and computer engineering graduates produced by these departments have a deep understanding of AI technology when they enter the Information Technology (IT) industry. These graduates will be key role players in the development of AI technology, customising it for the local context and developing basic AI courses that can be offered to students across all disciplines beyond Computer Science.

10.3 Develop AI tools, standards, and platforms

AI development tools and experimental platforms allow developers to rapidly prototype and deploy AI solutions. There are numerous established open source and commercial AI development platforms. For example, there is TensorFlow and PyTorch that focuses on deep learning and Protégé editor focuses on ontology engineering and developing knowledge-based systems. Since there are robust open-source platforms that are freely available, there is a limited cost involved in establishing a small AI start-up company. However, navigating the plethora of tools available and upskilling can be daunting. As part of the national AI strategy, a suite of standard development tools must be identified and maintained. Expertise can then be established around these tools.

Customised in-country AI courses can be developed around these tools. This can therefore facilitate broad-based AI training and improve public access to AI.

10.4 Allocate specific resources for national AI initiatives

For AI development to flourish, African governments should invest resources in research and development. And also, they should encourage AI-led industrial development through incentives for the private sector. These incentives should place emphasis on the need to support the development of the national technological infrastructure. They should create an enabling environment and build capacity to incentivise suitably skilled workforce and bring other initiatives that are essential for industry to function and flourish in the future. Governments also need to support small-to-medium enterprises (SMEs) and entrepreneurs entering the AI space. This balanced approach is required so that it encourages innovation and investment in AI while protecting citizens and consumers. As with other technologies, national governments have a pivotal role to play as an adopter and user of AI itself. This requires the integration of AI in the workings of national governments and in-service delivery. Furthermore, national governments have access to massive amounts of data and through carefully structured open data. Thus, open government initiatives can help to demonstrate the beneficial use of AI.

10.5 Establishment of an AU institute to coordinate and support national AI strategy, resources, and initiatives

The AU should establish an overarching African Institute for AI, which can facilitate the development of, and connections between, national AI institutes throughout Africa. This institute can establish guidelines and principles for AI development in Africa. It can also coordinate regional and continental AI forums, societies, and networks. The new chairperson of the African Union, President Cyril Ramaphosa, proposed the establishment of an Africa AI Forum². This forum will serve as a platform to discuss the form and structure of such an institute. This institute could play a pivotal supportive role through initiatives such as:

- Establishing an AI network between African universities.
- Establishing a repository of key tools and facilitate access to expertise and training in these tools. Establishing best practises and advice on policy and regulatory frameworks for AI.

10.6 Conclusion

Each African Member State must formulate a clear and cohesive national in-country strategy for AI. This national strategy should constitute appropriate indicators that can be utilised to track progress, and iteratively assess the success and impact of policy interventions. Depending on their current level of AI readiness and availability of resources, the strategy should include the establishment of a national AI infrastructure, promotion of AI awareness, education and research, and the development of AI tools, standards, and platforms. Furthermore, African countries should design policy and regulatory interventions for AI and allocate specific resources for national AI initiatives. Moreover, the AU must establish an institute for AI to coordinate and support national AI strategy, resources, and initiatives. Additionally, emphasis must be placed on ensuring that there are training, awareness and education initiatives that are focused on demographic communities that are usually under-represented in technology development. These under-represented demographic communities include women and the handicapped population, to address the ethical concerns around bias often associated with AI. Moreover, for AI development to flourish, African governments should invest resources in research and development.

² <https://www.itweb.co.za/content/LPwQ5MlyVpzqNgkj>

They should encourage AI-led industrial development through incentives for the private sector. These incentives should place emphasis on the need to support the development of the national technological infrastructure. They should also create an enabling environment and build capacity to incentivise suitably skilled workforce and bring other initiatives that are essential for industry to function and flourish in the future. Governments also need to support small-to-medium enterprises (SMEs) and entrepreneurs entering the AI space. This balanced approach is required so that it encourages innovation and investment in AI while protecting citizens and consumers.

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Notes

AUDA-NEPAD

230 15th Road

Midrand

South Africa

Telephone +27 (0) 11 256 3600

E-mail: info@nepad.org

www.nepad.org



AUDA-NEPAD
AFRICAN UNION DEVELOPMENT AGENCY