African National Artificial Intelligence Strategies: A review, analysis and research agenda

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***Abstract*—** Some countries have developed their national artificial intelligence strategies (NAISs) while others have formed task forces to develop them. This study reviewed elements and concepts required to develop NAIS, related science, technology and innovation (STI) strategies, policies and manifestos. Some of these elements and concepts apply to both developing and developed countries while some others are specific to one of them. STI elements and concepts apply to artificial intelligence strategies since AI technology is a specialization of STI technologies. The concepts and elements identified by this study can aid strategy creators by providing important insights for creating NAISs. For instance, catch-up strategies based on learning from a country with similar past technology, catch-up successes, and others who have created NAISs are a low-cost way for developing and implementing NAISs.

***Keywords*—** *artificial intelligence, capability building, catch-up, leapfrogging, national artificial intelligence strategy*

I. Introduction

The artificial intelligence (AI) revolution is drastically transforming the world, and several countries view it as a transformative technology. AI solutions are useful to everyone, and governments should strategize to create AI-driven economies that solve diverse problems [1]. Developing AI strategies and policies will align actors' efforts and resources towards this goal. In fact, technology strategies enable countries to navigate the technology development landscape to achieve strategic goals.

In this context, AI has been defined in literature in different ways: As making computers act rationally and humanly, or as making computers think like humans and rationally [2]. Both identify AI as an enabling factor for developing applications that imitate humans to increase business, industries, governments and society competitiveness.

Within the many countries that missed the first industrial revolution, some were able to join the second and third revolutions. Meanwhile others will join the fourth industrial revolution, in which AI is known as one of its major drivers. However, those that fail to join the fourth revolution in its early phases will find it almost impossible to join later and will face a high poverty and unemployment crisis. The gap between those who catch up and those who fail is likely to be exponentially larger than the gap created by the previous three industrial revolutions.

Several national technology strategies have been developed in the African continent. The latest of these strategies are national innovation and ICT strategies. However, most national ICT strategies do not even mention AI. One way to start developing AI capabilities at low cost is to add AI aspects to existing technology strategies. There is few AI courses offered in African higher education institutions. AI itself can be used to provide online courses at lower cost than physical classes.

Creators of national artificial intelligence strategies (NAISs) should start by assessing the country´s priorities, strengths and weakness; the possibility of deployment with the country's limited resources and citizens' aspirations [1]. A NAIS building on citizens' aspirations will get national implementation support. In addition, citizens must be educated about the benefits of AI technologies and NAIS.

Technology breakthroughs combined with large global investments are likely to establish technology dominance. Dominant technologies like the Internet drive competing technologies out of the market and force related technologies to become compatible with it. If AI becomes dominant, then ICT technologies including mobile applications and Internet of Things (IoT) will have to become AI compatible to remain competitive.

NAIS aligned with other specific and general technology strategies, creates a system of strategies that work together to achieve national objectives. Designing a new national strategy should align with other strategies and those likely to be developed soon.

The current research questions are:

1. What concepts, elements and catch-up lessons identified in literature are necessary for creating national AI strategies (NAIS)?
2. Which technology concepts, elements and catch-up lessons learned are relevant for creating African NAISs?

II. METHODOLOGY

The study used two research methods: the literature review, research method [3] and Conjecture Analogy design science method (CADSRM) [4]. The search was conducted to find relevant NAIS studies. CADSRM analogy determined similarities between literature and requirements for creating African NAIS.

Most literature reviews focus on the past. Some identify future research agendas, but few extend the literature by

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taking steps into the future. Reviews are based on what is published, and extending into the future involves exploring the unknown. A literature review is a springboard for future research [5]. Strategies are tools for navigating an organization´s future and a literature review provides a springboard into that future.

A literature review is concept-centric and organized around concepts. It should analyze the literature, identify knowledge gaps and encourage researchers to address them [3]. Gaps in knowledge for developing NAIS strategy limit the efficiency and effectiveness of the strategies created.

The CADSRM research method supports research, innovation and learning from one's experience as well as the experience of others. Developing countries (DCs) can benefit by learning from their experience of areas they have successfully leapfrogged, from other technological strategies they have developed as well as from NAIS of the countries that are leaders in AI technology.

The search string concatenated the terms: "African", "national science", "technology", "strategy", "policy", "manifesto", "innovation", "system", "adoption", "lesson learnt" and "technology success". The search terms were applied to Google, Taylor and Francis, IEEE explore and Springer databases. The search found one hundred and sixty (160) articles, which were then screened for relevance. This resulted in forty-nine (49) articles being included based on their abstracts. After a full-text reading, forty-five (45). relevant articles remained. The CADSRM method was used to identify concepts and elements in relevant articles for creating an AI catch-up strategy for Africa.

III. RESULTS

The results are organized into sub sections: NAIS concepts, related strategies and learning from past successes.

A. Elements of a national AI strategy

NAIS key pillars are AI in government and public services; skills and education; research and development; data, digital infrastructure and ethics [6]. The AI revolution should be guided by ethics, as it aims to make computers act and think intelligently like humans, which raises many ethical issues. To join the AI race, countries that are behind should start by providing resources to training institutions to build knowledge and skills and develop AI infrastructure. Educational institutions should integrate AI and related fields in their curricula [7]. Skilled manpower is the most critical component of building AI capability. Governments should initiate AI projects, including some open source to create avenues for beginners to acquire skills, experience and build capabilities.

A comparative analysis of developing countries, NAIS can help shed light on important elements that need to be included or excluded in the strategy [8]. The comparison can help identify the starting points of other countries and directions they took, allowing strategy creators to select suitable approaches for their countries. A government's NAIS strategy sets AI strategic directions for AI, shaping market structure and societal outcomes [9]. Designing flexible strategies helps overcome future challenges.

NAIS should set high-level priorities based on the country's future vision [10]. The vision determines a country´s focus and aligns sets of strategies. Lessons learned for creating national ICT strategies in DCs include involving citizens and aligning strategies [11]. Changes in government do not affect African national visions because they represent national interest agreed upon by most stakeholders.

For AI to become widely used, it should focus on mobile phones which are widely available in sectors like education and business that have large potential adopters [12]. This creates the possibility of commercial success for applications and AI becoming widely used.

B. Artificial intelligence strategy concepts

Mauritius was the first African country to develop NAIS [13]; a few others have followed, while many have established task forces. Experts from academia, industry and government drafted Ghana's AI innovation and adoption strategy [7]. The three categories of experts ensure viewpoints of different sectors are included. Forward thinking governments are creating comprehensive NAIS to leverage AI's transformative power [6]. This process requires identifying areas where AI will have transformative effects. Several countries are moving quickly to be early AI adopters, especially regionally, to obtain or maintain competitive advantage [13]. A SWOT analysis is used to determine whether to create an AI strategy that integrates both innovation and adoption or starts with adoption followed by innovation.

Countries should start by building basic AI skills, then proceed incrementally to more advanced skills. Assisted intelligence helps people perform tasks better, augmented intelligence assists people do what they could not, and autonomous intelligence creates machines that replace people's roles [14]. Augmented intelligence and autonomous machines represent the next generations of AI. The current generation is predominantly assisted intelligence, with few simple examples of augmented intelligence and even fewer examples of autonomous intelligence. Innovation capability, defined as the ability to generate innovative artifacts [15], will be essential to create next AI generation technologies. Strategies are future predictions modified as emerging trends become clearer over time.

Benchmarking is an analogical approach of learning and building capabilities by extracting best practices, methods and processes from organizations and countries that are more successful to achieve similar performance [16]. Countries are benchmarking their NAIS instead of reinventing what has already been developed elsewhere. Benchmarking can be done at regional [17] and at other levels. Innovation and design literature indicates countries apply benchmarking to national technology strategies, research, knowledge transfer mechanisms, networks and clusters, [18]. NAIS shows how a country plans to navigate the landscapes of the AI technology revolution.

An entity imitates another's better performing entity to learn by analogy from it. *Mix and match*, also called benchmarking, involves an imitator that mixes and matches practices of several competing firms. On the other hand, *Copying the Best* refers to an imitator identifying the best performing firms and copying a subset of observable practices from them [19]. Mix and Match produces a more diverse set of best practices compared to Copy the Best. NAIS are

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observable as they are available to all AI actors in a country and often available on the web.

African NAIS benchmarking against India, China, United Kingdom, Canada and United Arab Emirates is a strategy creation approach [20] in which best practices are selected from benchmarking, adapted and adjusted when creating new strategies. China's strategy is to become the leading AI power [21]; United Kingdom aims to improve its position as an AI technology developer [22]; Canada seeks to improve AI research and training profile [23]; India explores how to leverage AI transformation power for inclusive growth aligned with its government's philosophy [8]; and the UAE plans to use AI to improve government at all levels [24]. National strategies drive building skills, capabilities, business ecosystems and establishing industries efficiently and effectively. Efficiency maximizes the ratio of inputs to outputs and effectiveness maximizes the number of goals met [25]. A strategic plan sets the direction for a desired future destination. Sampene et al. [20] categorizes the best practices in African NAIS benchmark into inclusive growth, innovation, continental leadership, improving AI training and technology development. Countries worldwide apply NAIS benchmarking to create competitive advantage [13]. However, [20] do not indicate criteria for selecting the best practice categories from NAIS strategies in the benchmark. More research is needed on creating NAIS strategy benchmarks.

China is an exemplar of a large developing country in catching-up AI; the United States (US) is a leader in basic and applied research and development (RD) and invention. The US is leading in quality of AI publications and the number of patents. China's and other countries' AI catch-up capabilities were created by learning from the US. The US strategy should be included in the African NAIS benchmark as well as strategies for South America and other countries.

C. Science, technology and innovation strategy, policy and manifesto concepts

AI history is filled with many promises, some of which were not realized. AI inability to meet its promises is a risk to be managed.

African national information technology (IT) strategies should include general public's needs, be adaptable, adjustable and have a section on every domain of IT, including national development and training needs for five years or more [26]. NAIS is an IT technology strategy, and having these characteristics is an added advantage. AI technology industries are in different stages of industry formation cycle. Each stage has different requirements. The innovation stage requires start-ups to use experimentation and trial and error, imitation stage requires informal research and development, while the growth stage requires formal RD by large firms [27]. Firms deciding to start developing specific AI technology must determine the stage of the industry formation cycle and the entry strategy.

The Informal sector is the largest employer in most developing countries, but its return on investment is very low. Innovation in the informal sector is based on grassroots innovation that innovates by trial and error and experimenting. The next generation of AI technology revolution will support grassroots innovation movements [28] and countries that embrace AI grassroots innovation will be able to drastically improve informal sector productivity. Informal sector grassroots innovation should be a major part of developing countries' NAIS.

The NAIS primary long-term goal is to ensure leadership position, using AI to increase global competiveness and address society challenges and development needs [8]. These are critical goals that every country aspires to achieve. However, competition for technology leadership is cutthroat and only countries with sufficient resources have good chances of being technology leaders. Some countries, instead of focusing on becoming overall AI technology leaders, are focusing on specific AI subfields and application domains. For example, Canada's AI strategy seeks to make it a global leader in AI education domain. Countries that are left far behind in AI should seek to become emerging or DCs technology leaders or followers.

AI strategies based on catch-up models can enable countries to leapfrog and reduce the gap with technology leaders based on incremental innovations. Radical AI innovation strategies in developing countries have a very low probability of success but can enable DCs to become technology leaders. They require large investments that are almost impossible to get and have high failure rates, making them very risky. The failure of DC's AI radical innovation project would have dire and almost irrecoverable consequences in all economic sectors.

Recommendations for rooting STI and AI in society for transformational revolution are: Rejecting knowledge dependence to make Africa a major producer and a funder of AI research, encouraging bottom-up innovation and new forms of innovation [29]. New forms of innovation like inclusive and grassroots innovations can be included in NAIS. To bridge the gap between scientists, technologists and industry, governments should promote transdisciplinary thinking and research centers [29]. Transdisciplinary artificial intelligence research can bridge different knowledge and skills silos enabling the utilization of knowledge locked in silos.

The NAIS strategy has elements of STI strategy goals: stimulate networking, create awareness, advice policy makers and include wide range of stakeholders [30]. Networking enables sharing knowledge and expertise. AI human networks enable knowledge to flow between members of a network for spreading awareness. Policy makers consult existing strategies to ensure that government agencies are working towards a common goal.

African countries can develop innovation capability by leveraging informal sector knowledge, indigenous knowledge, biodiversity and biotechnology [31]. Next AI generation will automate grassroots innovation based on collaboration of AI and human systems [28]. Every country is technology and knowledge leader in its indigenous technology and knowledge. Grassroots innovation uses informal and indigenous knowledge, and it is an important element in African STI capability building [31]. Mauritius' NAIS puts little emphasis on informal sector [13]. This sector is important for the continent's development. Countries ignore this sector at their own risk.

The pilot analysis of Nigerian STI policy indicated it pursued five industrialization strategies: focusing on appropriate technology RD, developing local design and production capacity, fostering interactions among universities, research institutions, industries and investors to generate innovations and promote entrepreneurial innovation

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[31]. These strategies generate new knowledge and develop capabilities to apply knowledge to innovate. Kenya's STI policy is to create an STI innovation culture, while Nigerian objective is to inculcate a culture of innovation [31]. Kenyan and Nigerian STI pilot studies indicated commonalities and different emphasis on distinct aspects. Organizations, national and regional innovation systems integration into global value chains are developing into increasing global innovation systems [30]. Increased networking and collaboration among different African innovation system actors facilitate the commercialization of research and innovation [32]. Integrating African STIs ecosystems into national innovation systems through global networks will benefit from global research and experience.

D. Learning from past technological successes

Experience is important in technology development, and it is the reason why organizations often prefer employing experts over novices. Novices are good for generating radical ideas, many of which fail but those that succeed have a large impact. Experts are better at generating incremental ideas, many of which succeed but have relatively smaller impact [33]. Expertise levels apply to individuals, organizations and countries. Countries joining the AI race rely on ideas and efforts of both novices and experts.

Africa is beginning to significantly learn and master many AI technologies. A novice can only create new technology and management innovation like a strategy by reference to an example [34]. It is, therefore, more efficient and effective for Africa to learn from its past technological successes as well as learn from other countries by imitating.

The African countries used low-cost catch-up strategies to build their initial education and technology systems after independence. They had to build working systems within a short time and with very limited resources. Catch-up literature is vast and two Kenyan catch-up cases, one in education and other mobile money transfer, are used. Analogy-inspired approaches provide a way of systematically learning and leveraging similar past experiences to solve new problems. The most widely used analogy-based learning approach is design by analogy, also called analogy-inspired design. Design by analogy can enable learning from past success, the experiences of others and from biology through innovation and research [35]. The African AI strategy benchmark provides a means to learn from suitable strategies of other countries.

Kenya faced the challenge of introducing computing degree programs because of the lack of skilled trainers, practitioners and computing infrastructure. Without them, the mobile telecommunication and mobile money transfer revolution would not have succeeded. Kenya started a postgraduate computing degree by introducing a one-year postgraduate diploma in AI. One-year postgraduate diploma courses are more affordable and produce graduates more quickly than master's and PhD programs. This enables those without a computing background to be able to join the field. The initial idea was to start with a postgraduate diploma to create necessary foundations for starting master's programs. However, today many African countries have few AI master's degrees and face a lack of critical mass of graduates to carry out the AI revolution.

Kenya used frugal improvisation to transform personnel from science, technology, engineering and mathematics disciplines, who had studied in computing areas in Master's and PhDs degrees, into undergraduate computing lecturers. The first postgraduate degree was introduced at the University of Nairobi, providing the foundations for introducing computing master's degrees. Many students from different non-computing disciplines were able to use this degree to transition into computing fields and become computing practitioners. Some went into pursuing master's and PhD degrees abroad, and later returned to help create the critical mass to start computing master's and PhD degree programs. While this was not an ideal solution, it was low-cost and affordable, making graduate computing programs feasible. Sometimes, affordability is the most critical success factor for catching up.

A country can analyze whether it can manage with an average upgradable solution or wait for a better solution that it is not guaranteed to create. Another example of education is Jean School at Kabete, which at independence, used frugality to improvise teaching aids and necessary equipment [36]. The institution has grown to become one of the major technical colleges in Kenya. Frugal innovation and improvisation were possibly the most successful strategies that triggered the establishment of technology foundations of African countries at independence. Frugal innovation, combined with design thinking, can support DCs innovation and entrepreneurship [36] needed to establish AI industries. Research on frugal AI innovation could help both in introducing AI in the informal technology sector, and in automating other ignored areas.

Africa's leapfrogging in mobile communications, money transfer, solar energy and lessons from Chinese education and technology are applicable to the design of DCs leapfrogging strategies [37]. Technology leapfrogging refers to skipping low-grade and costly technologies and industries in favor of more effective and advanced technologies [38]. Leapfrogging experience creates mental models and builds capabilities within a country. Nations can build on these mental models and capabilities from previous technology leapfrogging. Kenya's MPESA mobile money transfer leapfrogging leveraged existing mental models, such as mobile vehicle banking and the practice of employees working in towns sending money by public transport vehicles to their rural relatives [39]. The most important resource for technological catch-up, leapfrogging and job creation for Africa's large unemployed youth in Africa is human capital [37]. Some evidence of this is all African countries have slogans like "the youth is the greatest asset these countries have".

AI is a major driver of Industry 4.0. All national technology strategies should be aligned since they work towards the same STI strategic goals. The commonly studied strategy alignment in computing is between business and IT strategies. Aligning business and IT strategies is an effective way to create efficiency and achieve targets for any business [40]. Organizations that align their strategies benefit from related organization elements working as a system, which creates synergy. African NAISs can follow either bottom-up or top-down strategies [41]. Strategy creators can decide which bottom-up, top-down, middle-out or a combination of strategies are appropriate.

For DCs, incremental innovation is better than radical innovation as it is cheaper, less risky and enables firms to innovate by imitating solutions from other parts of the world [42]. They creatively imitate and retranslate existing solutions from other industries such as technologies, patents, specific knowledge, capabilities, general principles, business processes and whole business models [43]. Chinese, Japanese and South Korean SMEs have used imitation by breaking down and reassembling products or creatively imitating or importing and improving upon the best knowledge, experiences and solutions [44]. In Japan, the culture of imitation has existed for five centuries, where individual entrepreneurs invented a product, then other entrepreneurs imitated inventors and firms commercialized invented solutions [44]. Imitation that *learns by analogy* is often cheaper than invention. A pattern of expertise levels derived from Japanese martial artists, consisting of learning, detaching and transcending was used as the basis for creating agile method developers' capability-building model [45]. The Agile methods have since been adapted for AI technology development. The first example is learning by analogy from an indigenous system on how to create a modern technology innovation. The second example is how artificial intelligence learned how to apply a software engineering method.

The mindset that imitation is embarrassing is misleading. Business leaders should see imitation not as an inhibitor but as an enabler of innovation, but risks are not to be ignored [46]. Imitation is often viewed by business, society and academia negatively as something to avoid. Imitation that is unethical or that violates intellectual property is negative. Blind imitation copies non-beneficial elements while smart imitation copies only useful elements and invents others. Several countries, such as China, Japan and South Korea as well as many firms have been able to catch-up based on imitation. One-way startups create imitation competitive advantage through learning by analogy from technology leaders' new product development: cheaply and with fewer resources, to create their own innovations [47]. Startups can also learn by imitating processes, start-up creation and growth approaches from developed countries. For example, Tanzania can learn from European and Asian SMEs along with start-ups experiences on how to combine imitation and innovation to overcome limited research and development capacity; and infrastructure constraints to catch-up in science, technology and innovation [48]. AI Invention strategy is largely preferred over Imitation strategy in Africa. Tencent used an imitation strategy to develop its first product by copying good elements from an American company and substituting not-so-good elements with innovative others to grow [49]. Literature provides many examples of individuals, groups, firms, communities and countries catching up through learning by imitation.

IV. CONCLUSION

Some of the core concepts for African countries in creating NAIS strategies include capability building, learning from past technology building successes like mobile money transfer; and using follower and catch-up strategies. These concepts are necessary to create strategies with sound theoretical foundation that could work.

African countries can learn from their past successes to upgrade AI education, research and development, and to set up necessary infrastructure. The technology leapfrogging strategy was the force that drove mobile money revolution. These are exemplary technology leapfrogging cases.

NAIS can help align national thinking and efforts in a common direction, providing a more effective and efficient way of building national AI capabilities. Failing to plan is planning to fail. A strategy is a form of planning and failure to create an AI catch-up strategy is, in effect, like creating an AI strategy to fail. Making large investments in AI without establishing prerequisite foundations is likely to lead to failure. Knowledge and research should be the basis of such investments.

In the past, AI made many great promises, some were realized while others were empty promises. Today, AI still presents as many threats as opportunities. To deal with these, most of AI technology leaders invest short-term in less risky incremental innovations and long-term in highly risky radical innovations. Followers invest in incremental innovations or in building capabilities to build commercial applications and continuously upgrade applications and capabilities.

There is little research on African information and communication technology catch-up, although it is an important source of learning. Literature reviews can provide foundations for future catch-up research and provide a quick reference for those interested in catch-up research like policy makers.

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