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AFRICA 4TH INDUSTRIAL REVOLUTION STANDARDIZATION STRATEGY (2021–2025)

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- Smart Africa
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EXECUTIVE SUMMARY

The African Fourth Industrial Revolution Standardization Strategy seeks to provide direction on standardization for the well-being of Africans in the global economy. The strategy also seeks to bridge the gap between the physical and digital world, through collaboration of standardization experts, technology communities, stakeholders and regulatory agencies in assessing industry standards and policy harmonization that enhances trade within the Africa Continental Free Trade Agreement (AfCFTA) single market. The strategy also sets to positioning standards as the key driver and enabler of economic activities, enhancing standards development, using standardization to enable competitiveness of goods and services, adaptation of standardization best practices, institutionalization of effective management and coordination of standardization, taking active leadership role, aligning with other national and regional policies in relation to industry, consumers and environment and finally to facilitate coordination and scaling up standardization in Africa and to provide access to relevant standardization information.

Through the preferred Theory of Change (ToC) the strategy identifies activities that would contribute to improved approaches and coordination of standardization in the 4IR in Africa. The development of the strategy that brought together standards organizations, standards development contributors, research organizations, regulatory agencies, technology producers, and software developers represents the shared vision and aspirations of a broad cross-section of and diverse standards stakeholders in Africa.

The Fourth Industrial Revolution (4IR) provides organizations with opportunities for not only optimizing and enhancing internal operations, but also to innovate and optimize business models. The conceptual model revolves around the four domains of strategic choices namely, strategic execution, technology potential, competitive potential, and service level. The interrelationships of four domains inform the technology aspect, focusing on implementing the chosen business strategy and recognizing the need to address both external and internal domains.

Central to the A4IR Standardization Strategy are the following:

- Balanced standardization policies and collaboration between state and non-state actors
- Balanced data policies
- Capacity building and skill development to enhance productivity
- Continuous experimentation for cyber-physical systems
- Integration of measurements, learning and reporting, and information dissemination

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AFRICA 4TH INDUSTRIAL REVOLUTION STANDARDIZATION STRATEGY (2021–2025)

1. PREAMBLE

The Fourth Industrial Revolution is heralding the development of new techniques and business models. These will fundamentally transform production processes, government decisions, industry, and the society at large. Trust, policy networks, learning by doing, and collaboration between different social actors are critical success factors. They are also areas of greatest challenge for African countries that are generally characterized by high levels of inequality, low trust between social actors, centralized government, industry concentration and higher costs of search, discovery and failure. Despite these challenges and uncertainties, opportunities abound for African countries to work with global and regional standardization experts such as African Organisation for Standardisation (ARSO) and IEEE Standards Association (IEEE SA) on the development of effective standardization strategies. These can lead to improved economies of production, better planning, and effective control and reduced production costs, leading to higher returns on investment (profit).

The Institute of Electrical and Electronics Engineers Standards Association (IEEE SA), a global voluntary standards development organization, and the African Organization for Standardization (ARSO), a pan-African standards development organization under the auspices of the African Union, are organizations that both develop standards relevant to the Fourth Industrial Revolution, otherwise known as 4IR. The principal mandate of ARSO is to harmonize African Standards and conformity assessment procedures in order to reduce technical barriers to trade to enhance intra-African and international trade as well as industrialization and integration in Africa.

This project aims to identify standardization strategies and gaps through institutional coordination of the African Standardization Strategy for the Fourth Industrial Revolution.

2. ACRONYMS

Acronyms used in this paper are as follows:

AfFCTA	Africa Continental Free Trade Area
A4IR	African Standardization Strategy for the 4th Industrial Revolution Industry Connections Program
A4IRSS	A4IR Standardization Strategy
AECDI	African e-Commerce Development International
AfDec	African Declaration on Internet Rights and Freedoms
AfCFTA	Africa Continental Free Trade Agreement

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AFSEC	African Electrotechnical Standardization Commission
AI	artificial intelligence
ARSO	African Organisation for Standardisation
AUDA-NEPAD	African Union Development Agency–New Partnership for Africa's Development
CSIR	Council for Scientific and Industrial Research
CSOs	civil society organizations
DeKUT	Dedan Kimathi University of Technology
A4IR	Africa Fourth Industrial Revolution
IoT	Internet of Things
IIoT	Industrial Internet of Things
IEEE SA	Institute of Electrical and Electronics Engineers Standards Association
SO	strategic objective
ToC	Theory of Change
SAZ	Standards Association of Zimbabwe
UNECA	United Nations Economic Commission for Africa

3. SCOPE AND APPROACH

The Standardization Strategy adopts a Theory of Change (ToC) approach. The ToC identifies activities that should be undertaken by the project that would contribute to a chain of results leading to improved approaches and coordination of standardization in the 4IR in Africa. The strategy, which is designed to be widely recognized and adopted due to its recognition of change as non-linear requiring review, reflection and revision of strategy, was developed through the coordinated efforts of the A4IR participants. These represent standards organizations, standards development contributors, research organizations, regulatory agencies, technology producers, and software developers committed to empowering societies. Through the process, all participants expressed commitment to developing the standardization strategy in an open, balanced and transparent manner, leveraging the IEEE SA Industry Connections platform. The result is a document that represents the shared vision and aspirations of a broad cross-section of standards stakeholders reflecting the diversity of the face of Africa.

4. PURPOSE

The A4IRSS provides direction for Africa's leadership at national, regional and continental level on how best to use standardization to advance the interests and well-being of Africans in the global economy. It is based on the following considerations:

- Positioning technical standards as a key driver and enabler of all economic activities relating to cyber-physical systems
- Developing a conducive environment in Africa for standards development, taking into account the diversity, interests and expertise available

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- Using standards as an enabler of competitiveness of African goods and services in domestic and international markets
- Adopting best practices and innovation in standardization, conformity assessment and technical regulations
- Creating integrated infrastructure, roadmaps and institutions for effective management and coordination of standardization
- Playing an active role in taking up leadership positions internationally or in related areas
- Aligning the A4IRSS with other regional and national policies related to industry, consumers and environment
- Offering the A4IRSS to stakeholders on the continent to facilitate coordination and scaling in context of the Africa Continental Free Trade Agreement (AfCFTA), and for regulatory and policy stakeholders to be able to more efficiently access relevant standardization information

5. DEFINING A4IR.

WHAT IS THE 4TH INDUSTRIAL REVOLUTION?

The terminology 'Fourth Industrial Revolution' is more recently evolved, but its enabling technologies, which are shown in FIGURE 1, have been around for decades and have massively benefitted several industries. 4IR is characterized by cyber-physical systems (CPS) that allow for the merging of real and virtual worlds in real time.

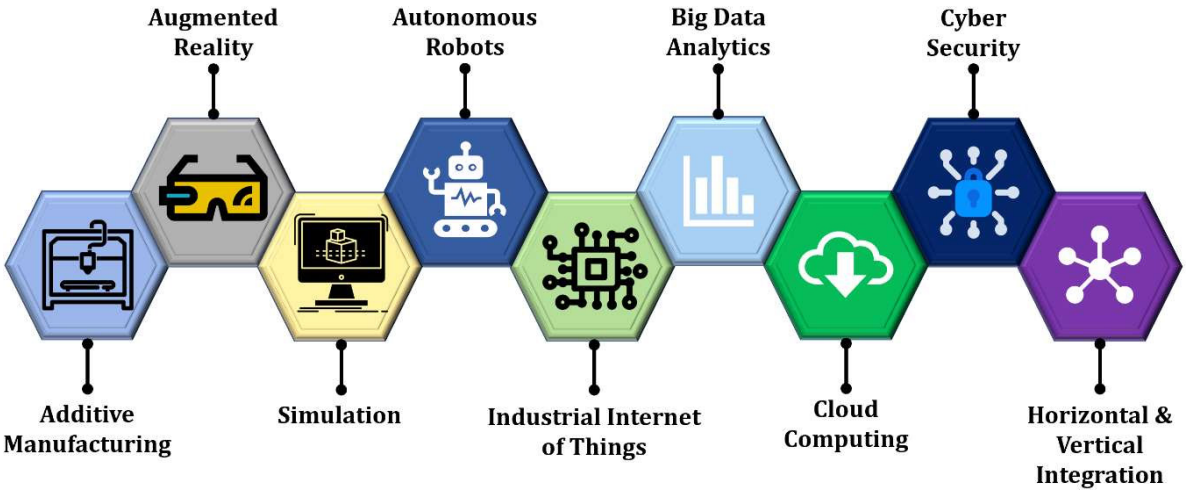

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FIGURE 1 Enabling technologies of the Fourth Industrial Revolution

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While there is no universally accepted definition of the Fourth Industrial Revolution, there are commonly accepted aspects of it. The Fourth Industrial Revolution is commonly defined in terms of cyber-physical systems, internet of things (IoT), internet of services, and smart factory. This definition is utilized to propose six design principles that can support companies in identifying and implementing 4IRscenarios. These are as follows:

1) Interoperability
2) Virtualization
3) Decentralization
4) Real-time capability
5) Service orientation
6) Modularity

African countries that have manufacturing expertise are funding initiatives that can position them as promoters of advanced manufacturing facilities. The focus, however, differs from the European countries, UK, and USA being focused on developing business and standardization models, and countries like Japan, Germany, and China implementing digitization, to increase efficiency and product quality, as well as reduce costs.

The challenges to adoption include, but are not limited to, the following:

- Low understanding of 4IR implications
- Lack of knowledge and unified leadership
- Inability to accurately estimate return on investment
- Legal issues
- Data ownership
- Lack of digital culture
- Lack of digitally competent workforce
- Lack of infrastructure and internet-based services
- Reluctant behavior toward 4IR
- Security issues
- Financial constraints

The potential benefits offered by the 4IR have created a ripple effect where organizations are strategically planning to move toward digital transformation to enhance their competitiveness in the market. However, this is not an easy task and requires a long-term commitment to ensure that a transition from the conventional to the digital will be made successfully. Adoption of 4IR requires new strategies, organizational models, and organization-wide changes in physical infrastructure, manufacturing operations/technologies, human resources, management of practices, and change management. This is a challenge for small/medium companies. Large organizations can also be overwhelmed, especially when they are not the experts for a move toward digital transformation.

The above discussion is summarized in TABLE 1 and forms the basis for understanding technological considerations for the development of a strategic roadmap.

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TABLE 1 Opportunities offered by 4IR enabling technologies

No.	4IR Enabling Technologies	Opportunities	Development Strategies
1	Additive Manufacturing	Design flexibility, reduced set-up and tooling time, lightweight and customized products, less waste, effective for mass production of both large-scale and small-scale structures	▪ Smart manufacturing ▪ Strategic management ▪ Innovation management ▪ Information/data management ▪ IT maturity and governance ▪ Smart supply-chain management ▪ Cross-functional IT integration ▪ Technology management ▪ Marketing ▪ IIoT management ▪ Human resources ▪ Customer ▪ Legal practices ▪ Change management ▪ Risk management ▪ Project management
2	Augmented Reality	Faster and smarter product development and assembly, enhanced operator performance, expert support provision, effective machine maintenance and quality assurance	
3	Simulation	Optimized product/process parameters, reduced investment risk, waste minimization, allows faster prototyping, virtual analysis of complex scenarios	
4	Autonomous Robots	Increased efficiency and productivity, reduced error and re-work, operator safety, exponential learning by collecting and analyzing machine data	
5	Industrial Internet of Things	Interconnected systems, production visibility, better inventory management, safe working environment, reduced machine downtime, increased quality	
6	Big Data Analytics	Asset/supply chain optimization, product design/quality, better future forecasting and identification of trends, higher customer satisfaction	
7	Cloud Computing	Low capital costs, flexibility of the operations, disaster recovery, automatic software updates, increased collaboration, freedom of operation, data security, opportunities for up-skilling workforce	
8	Cyber Security	Protection of and reduced risk of hacking, inspires customer confidence, increased productivity, protection against spyware, worms, and viruses	
9	Horizontal and Vertical Integration	Optimize supply chain, increase differentiation from competition, high productivity, superior product quality, less waste, reduce set-up costs, errors, and machine downtime	

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Cutting-edge and disruptive technologies emerging from the 4IR such as IoT, internet of services, and cyber-physical systems present new ways in which organizations can conduct business. Organizations require a detailed strategic and technological plan to optimize the benefits of the 4IR and to become digital organizations. The aim of 4IR is to realize improved operational efficiency and productivity. This could be achieved through features such

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as digitization, optimization, production customization, automation, and adaptation. Furthermore, human-machine interaction enables enhanced value-added services, automatic data exchange, and communication. These features are also strongly associated with industrial value-adding processes, knowledge management, internet technologies, and advanced algorithms and are applied across three areas of impact, namely integration of value chains (IoT, cloud computing, etc.), digitization of offerings (e.g, augmented reality, smart sensors, big data analytics), and digital business models and customer access (authentication, artificial intelligence, etc.).

The 4IR provides organizations with opportunities to

- Optimize and enhance internal operations
- Innovate and optimize business models

It is important that organizations understand the realities of the 4IR in order to exploit its business value in an organizational context, while maintaining strategic alignment. The conceptual model is built across the four domains of strategic choices: service level, competitive potential, technology potential, and strategic execution (see FIGURE 2).

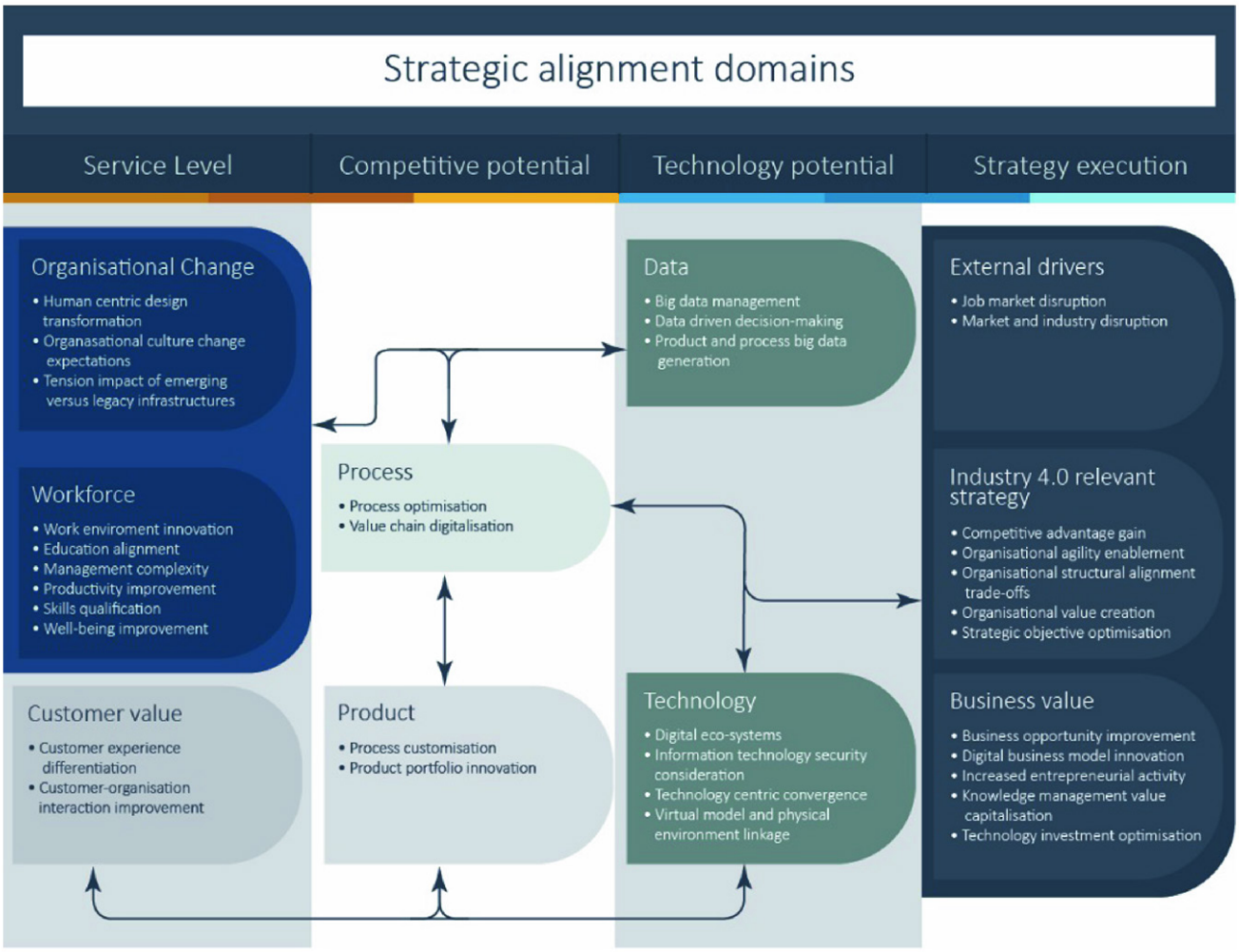

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FIGURE 2 Strategic organizational perspectives of 4IR aspects

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These four strategic alignment domains also present interrelationships (denoted by arrows), as the business strategy informs the technology aspect, focusing on implementing the chosen business strategy and recognizing the need to address both external and internal domains. In terms of defining strategies, the next step is the assessment of the existing workforce skill set and future training needs. The 4IR will not be able to make a significant difference if it is opposed by the organization's existing workforce. The design principles and technology trends of 4IR (such as horizontal and vertical integration, IIoT, CPS, interoperability, simulation, and block chain) indicate that the fourth industrial revolution is all about IT.

6. AFRICA'S 4TH INDUSTRIAL REVOLUTION STANDARDS

Due to the broad scope of 4IR, initiative participants decided to structure the discussion around use cases and standards. This approach aggregates different viewpoints on the topic of 4IR and enables well-scoped discussions around specific use cases and standards. While many discussions around 4IR pertain to information and communication-related aspects, functional aspects and business aspects may undergo important changes too. The Africa 4IR standard should define the following layers:

1) Business layer: This layer concerns 4IR business models, assures integrity of 4IR functions in the value stream, and looks at legal and regulatory conditions.
2) Function layer: Integrating different assets in an 4IR factory or plant may require a formalization of their functionality.
3) Information layer: Each entity should provide information about itself in machine-readable and possibly standardized formats.
4) Communication layer: 4IR requires appropriate protocols to communicate the information and functions of assets among each other.
5) Integration layer: This layer is concerned with the challenge of bringing machines, robots, products, and virtual entities into the IT world.
6) Asset layer: Finally, the asset layer includes physical components, such as robots, machine, pipes, motors, automated guided vehicles, but also human beings.

Finally, the Africa Fourth Industrial Revolution (A4IR) standard should consider different plant hierarchy levels to scope discussions. These include the following levels:

- Product: for example, IoT-enabled products
- Field device: for example, smart 4IR sensors
- Control device: for example, programmable logic controllers
- Station: for example, the capper station in a bottle-filling machine
- Work center: for example, a building or plant segment for a batch process
- Enterprise: for example, a company in beverage production
- Connected world: for example, a cloud platform for different supply chain participants

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At the heart of digitalization, an essential idea is to unlock opportunities offered by analyzing data. By collecting data from production assets, processes, materials, and products, one can gain deeper insights into the production process and optimize its operational aspects for higher productivity. However, making vast amounts of data available in centralized locations is both an opportunity and a challenge for manufacturers and service providers. On the one hand, this opens up a new data analytics market with new business models, and allows improving production without added capital investment, protecting above all the existing investment into machines. On the other hand, it requires data from a variety of distributed data sources to be easily understood, e.g., by data Scientists or subject-matter experts to devise and operate the value-based services.

7. DIGITAL TRANSFORMATION OF MANUFACTURING IN THE FOURTH INDUSTRIAL REVOLUTION: IMPLICATIONS FOR AFRICA AND STRATEGY GOING FORWARD

The UN Committee for Development Policy argues that developing country growth cannot be sustained if not supported by necessary capabilities and an appropriate policy framework 2. At the domestic level, African countries therefore not only need to build productive capabilities, they also need to build governance capabilities and investment mechanisms that enable them to design and implement appropriate policies for dynamic structural transformation. The agreement establishing the African Continental Free Trade Area (AfCFTA) came into force in May 2019. Ultimately the AfCFTA is designed to create a comprehensive African market; what it does at this stage is set in motion a set of complex and foreseeably very lengthy negotiations. The outcome of that process will not yet be full free trade in Africa, but it will bring about a reduction in tariffs with the potential to stimulate production and trade and boost regional value chains.

Fifty-four African states have signed the agreement establishing the AfCFTA, and twenty-eight have also ratified it (as of October 2019). In essence, the point of the AfCFTA is to abolish tariffs on 90% of goods tariff lines. For the most sensitive 7% of products the process will be phased over a period of ten to fifteen years; 3% of tariff lines (not exceeding 10% of the value of imports) will enjoy permanent protection (Schmieg, (2020). The AfCFTA agreement ultimately merges the 54 African countries into a single market of 1.3 billion people. This resource, with the merit of enhancing sustainable markets, could create an economic bloc with a combined GDP of $3.4 trillion. Once in place, intra-African trade is expected to grow by 33%, and Africa's total trade deficit is expected to be cut in half. In addition, the AfCFTA could generate combined consumer and business spending of $6.7 trillion by 2030, according to the Mo Ibrahim Foundation (Mo-Ibrahim, 2019). AfCFTA is not simply a free trade agreement; it is a vehicle for Africa's economic transformation. Through its various protocols, it would also facilitate the movement of persons and labor, competition, investment, and intellectual property (ACT, 2020).

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8. VISION, MISSION, AND VALUES

8.1. VISION STATEMENT

The vision statement is as follows:

Moving towards digital transformation to enhance competitiveness of the African Continental Free Trade Area (AfCFTA) through promotion of harmonization of standards under a single market.

8.2. MISSION

The mission of A4IR Standardization Strategy is to bridge the gap between the physical and digital world, through increased collaboration between international and regional standardization experts, technology communities, stakeholders and regulatory agencies; to assess industry standards and contribute towards policy harmonization for enhanced trade within the Africa Continental Free Trade Agreement single market.

8.3. VALUES

Five core values underpin the A4IR Strategy. They represent fundamental beliefs and ethical guidelines that guide implementation. These are inspired by the AU, ARSO, and IEEE's commitments and informed by global considerations around technology advancements for the Industry and ultimately societal benefit.

- Transparency, accountability, and integrity
- Creativity and innovation
- Trust
- Growth and nurturing
- Partnership and equitable collaboration

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9. PURPOSE AND GOALS

9.1. GOALS

The A4IR standardization strategy seeks to map out the path towards optimizing and scaling up A4IR standardization on the continent during the five-year period 2021–2025, identifying working modes and setting clear targets and achievable, measurable results.

The main goals of the A4IR Standardization Strategy are to enhance and promote the following under the AfCFTA:

- Harnessed potential of standardization to realize the 4th African Industrial Revolution's potential for the African continent
- Digital interoperability and cyber-physical systems experimentation through harmonized policies, frameworks, and voluntary standards
- Economic transformation through increased trade and industrial development
- Greater capacity in African economies and innovation centers
- Enhanced African representation in global standardization and technology governance environments

9.2. PRIMARY OBJECTIVES

The A4IR standardization strategy expects to achieve the previous goals through the following key objectives:

1) Thoughtful, balanced data policies to leverage existing data systematically and ethically, and ensure that new data can be generated accordingly.
2) Increased capacity building and skills development for enhanced productivity, trade, and industry under the AfCFTA single market.
3) Increased coordination and collaboration between state and non-state actors in Africa to enable availability of data from the continent for increased representation in development of new applications.
4) Continuous experimentation for a cyber-physical system enabled through infrastructure and identified software architecture properties and processes.
5) Integrate measurement, learning, and reporting frameworks into the A4IR strategy for the purpose of managing effectively for results, enhanced coordination, and information dissemination in Africa.

These objectives are outlined in more detail in the charts that follow.

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Overall Objective 1:

Thoughtful balanced data policies to leverage existing data systematically and ethically ensuring that new data can be generated accordingly.

Specific Objective 1.

Promote creation and integration of the Standards Roadmap for Africa into policy for coordinated and efficient implementation and response.

Justification

Standards are the basis of development of technology, and with the 4IR standards increasingly need to be interoperable at regional or even global levels. This requires broader coordination. Standards organizations and other stakeholders in Africa that participated in this strategy development process indicated that policy and regulatory environment is a leading enabler of 4IR to become a reality. The accelerating pace of technological innovation globally is spawning new businesses, transforming old ones, and redefining the rules of competitive success. The regional debate about the competitiveness of African industries and the role of stakeholders in improving it is increasingly becoming a debate about standardization policy. Unfortunately, there is no clear policy on 4IR in most African countries. A Standards Roadmap for Africa is key and must be integrated in policy and regulatory frameworks at national, regional, and continental levels, so that all innovations are properly managed while still taking into account ethical considerations of privacy protection and intellectual property of developers. If this is not done, 4IR realization will still be an illusion for the greater part of Africa save for a few pockets on the continent where some work is being done in the area of research and development. There must be appropriate coordination and cohesion; otherwise, the approach to the Fourth Industrial Revolution may risk being fractured/disjointed.

Failure to recognize and capitalize on 4IR opportunities, will impose considerable risks on African stakeholders: without attempts to move beyond existing models of innovation, entrepreneurship, and digital growth on the continent, African businesses risk falling further behind, exacerbating the global "digital divide" and lowering their global competitiveness. Going beyond the existing models requires discipline in governance to allow an endogenous innovative environment. At the same time, institutions must protect the market through consumer protection laws and regulations that encourage competition (Ndungu and Signe, 2020 [5]).

The availability of digital technologies in Africa can increase access to information, job opportunities, and services that improve standard of living. AI, IoT, and block chain can enhance opportunities for data gathering and analysis for more targeted and effective growth and development. But data needs to be inclusive. And that needs widespread connectivity in the continent. Through adequate reforms and investments to support the African aspirations to build a single African digital market, and building on a new digital transformation strategy, Africa can harness digitalization as a driver for growth across all sectors of economy.

Proposed strategic actions (for SO1)

The role of policy and regulatory frameworks in creating viable commercial models while balancing the needs of society, private companies, and government entities is vital. Regulatory frameworks enhance innovators' ability to design and apply new solutions and create better infrastructure systems.

- Develop a 4IR Standards Roadmap for Africa, that can help meet the continental need for 4IR standards.
- Realization of 4IR in Africa requires establishment of a regulatory environment for competitive and harmonized regional connectivity markets. Unfolding the potential benefits of digitization requires a robust regulatory framework, in areas such as data and consumer protection, digital financial services, cybercrime, and e-governance. Specific policies are required to ensure full digital inclusion and digital equality for all communities.

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Overall Objective 2

Increased capacity building and skills development for enhanced productivity and trade under the AfCFTA single market for enhanced well-being of society through skills-aligned opportunities.

Specific Objective 2.

Unlock resources, knowledge, and skills for Africa to leverage opportunities under the A4IR.

Justification

Sub-Saharan Africa is home to 13% of the world's working age population; a number that is set to increase to more than 17% by 2030, the world's second largest after Asia. With more than 60% of its population under the age of 25, Sub-Saharan Africa is already the world's youngest region today and, by 2030, will be home to more than one-quarter of the world's total under-25 population. Over this period, the region is projected to expand the size of its workforce by more than the rest of the world combined (Annunziata and Kramer (2015) [2]), as its young population, the best-educated and globally connected the continent has ever had, enters the world of work. By leveraging this demographic opportunity, Sub-Saharan Africa has the potential to unleash new economic possibilities created by future industries and markets, dramatically raising labor productivity and per capita incomes, diversifying its economy, and becoming an engine for stable economic growth, high-skilled talent and job creation for decades to come (World Economic Forum, 2017 [10]). Today, however, Sub-Saharan Africa is far removed from making optimal use of its human capital potential and under-prepared for the impending disruption to jobs and skills brought about by the Fourth Industrial Revolution (Ibid). An estimated 15 to 20 million increasingly well-educated young people are expected to join the African workforce every year for the next three decades. Delivering the quality jobs to match in order to fully leverage the continent's demographic opportunity is set to be one of Sub-Saharan Africa's defining challenges over the coming years. Simultaneously, the Fourth Industrial Revolution will interact with a range of additional socio-economic and demographic factors affecting the region, resulting in major disruptions to labor markets, growth in wholly new occupations, new ways of organizing and coordinating work, new skills requirements in all jobs and new tools to augment workers' capabilities (World Economic Forum, 2017 [10]). The correct skills and talent are critical in the ability to attract global trade and investment, availability of sustainable resources and a thriving demand environment. Large corporations with resources must play a central role in unlocking resources, knowledge, and skills for Africa to leverage opportunities under A4IR also through "Standards training" and incorporating importance of standards in education.

Proposed strategic actions (for SO2)

Laying a foundation for the continent's realization of 4IR requires deliberate policy approach, private sector commitment, and institutional reforms.

- It is vital for all sectors to invest in building skills to establish a sustainable pipeline of talent to meet future skills needs. As the current adoption rate of smart technologies is still relatively low, the key components of 4IR will put more pressure on areas in which the African continent is still struggling.
- 4IR economy calls for better digital skills and literacy and generates high demand for a qualified, local workforce in all sectors that can benefit from the 4IR transformation.

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Overall Objective 3

Increased coordination and collaboration between state and non-state actors in Africa to enable availability of data from the continent for increased representation in development of new technological and service applications.

Specific Objective 3a.

Promote more state, institutional and private sector collaboration learning and conversation on the digital divide and the geo-political gap which makes realization of A4IR difficult. This includes new norms for private sector industries and cross border trade.

Justification

The 4IR is heralding the development of new techniques and business models. These will fundamentally transform production processes, government decisions, industry, and the society at large. Trust, policy networks, learning by doing, and collaboration between different social actors are critical success factors. They are also areas of greatest challenge for African countries that are generally characterized by high levels of inequality, low trust between social actors, centralized government, industry concentration and higher costs of research, discovery and failure. Therefore, conversation on the digital divide and the geo-political gap which makes realization of A4IR difficult are another critical objective. The Africa Continental Free Trade Agreement (AfCFTA) will play a major role by creating incentives to enhance current trends such as the digital economy in ways that meaningfully contribute to Africa's own growth. The African Continental Free Trade Agreement creates significant momentum for continental integration and the ultimate ambition of a continental single market. It will increase intra-African trade, diversify exports, and improve product quality and safety. Enhancement of coordination and collaboration between state and non-state actors in Africa will support the development of value chains that can contribute to an African Continental Free Trade Area.

Cross border cooperation can boost collaboration, inter-relations, and ultimately economic development within each participating African country and specific regions. The basis for it consists in the common interest for improvement of life standards, in ensuring a sustainable and harmonious framework and in the clearance of frontier barriers, restrictions, or other factors. In view of improving the social-economical position of the regional communities and removing of the negative effects of the border, the local communities should be more and more involved in the regional collaboration. The ICT sector is more amenable to private enterprise participation and although their participation has increased, the depth of this engagement is limited. This is primarily due to a host of factors such as: poor and inadequate infrastructure in rural areas where a majority of the population lives; poor institutional framework; concentration of such investments in the more profitable areas of the economy; poor local capital markets to facilitate the mobilization of funds to support these developments; lack of commitments and poor leadership within African countries to drive this evolution; and the perception of Africa as a high-risk continent with weak governance structures.

Proposed strategic actions (for SO3a)

There is need for a model that works for Africa where governments are positioned correctly and by encouraging partnerships with private sector stakeholders. Such a model would involve both urban and rural areas with the spurring of local economies promoting job creation and employment. It is therefore important that

- Solutions need to be discussed, developed, and adopted to drive implementation of A4IR effectively to enhance the AfCFTA's relevance and ability to address 21st century global developments and challenges. All state and non-state actors should be involved in these deliberations with a view to enhance knowledge, awareness, and confidence in the A4IR process, which is still in its infancy on the continent.
- Both the public and private sectors keep pace with advances in technology, and address the new regulatory frontiers and environment to support the digital transformation in order to achieve its

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full potential. The rapid growth in the technology sector is an indication of a positive shift towards the 4th Industrial Revolution.

- Partnerships are created and/or fostered with national standards bodies and regulatory agencies to promote investment opportunities. For instance, by scaling up the adoption of cyber-physical systems to improve sustainable efficient and safe connectivity between countries and continents. Cooperation and dialogue with both public and private sectors under AfCFTA as well as with other regional trade agreements are strategic tools through which this can be achieved.
- Partner with African states in adopting standards policies and regulatory reforms that improve the adoption of cyber-physical systems.
- The private sector could enormously benefit from incentives supporting industrial development, digitalization and greater integration, which in turn would result in greater opportunities for the growing youthful populations.
- Private sector manufacturers would be interested in an internationally-recognized certification procedure, based on established standards.
- The divide between the more economically and technologically advanced African countries and those that are less developed should be well considered, with actions towards bridging gaps and creating solutions for enhancing equality and equity as well as reduced cost of service and technology products.

Specific Objective 3b

Address critical standardization gaps: (e.g., lack of standardized application programming interfaces and common data languages) for the increased integration of self-sufficient systems as well as exposure to the dangers of cyber attacks.

Justification

- Africa comprises a significant 16% of the world's population, but its share in world trade is only 2.3%. At present, Africa is far behind other regions in contributing to global standardization, and this "standards divide" is seen as one of the major contributing factors for the continent's poor performance in international trade and lack of contribution to global standards.
- Proposed strategic actions.
- Consideration of the challenges/gaps and how they can be addressed through standards such as issues of poor quality products or conformity assessment/compliance of products to standards (product certification) need to be further explored and articulated going forward.
- Promote the active participation of the AfCFTA membership in the definition and adoption of international standards where these do not already exist or where they may need to be adjusted or adapted with a view to bridging the standardization gap.
- Partner with international standardization organizations to provide African countries with assistance to enhance capacity building in the standardization field.
- Identify ways and means to support the participation of standards bodies—or regulatory authorities that are responsible for exercising autonomous authority in a regulatory capacity—in standardization meetings and the dissemination of information on standardization.
- Collaborate with relevant regional organizations and support their work in standardization.
- A coordinated effort by industry and government leaders to boost standards certification in Africa will help narrow the current gap and enable the continent to become a more active player in international trade.

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Specific Objective 3c.

Reinforce state and institutional capacity to drive and support innovation and create an enabling business environment, which is essential for success of 4IR.

Justification

Africa is characterized by poor science, technology and innovation (STI) infrastructure, a small pool of researchers, low patronage of science and engineering programs, weak intellectual property frameworks, and low scientific output relative to the rest of the world. Most African countries have weak institutional capacity to develop and sustain STI, since few public institutions have adequately qualified human resources in science and engineering. In addition, African countries have weak capacity to retain the few qualified scientists and engineers, and the migration of African skilled scientists and other experts—the "brain drain"—has further depleted Africa's STI capacity. For instance, from 2007 to 2011, the number of tertiary-educated Africans who had migrated away from the continent was estimated at 450,000 (UN-DESA and OECD 2013 [9]). In effect, Africa's training institutions are subsidizing other regions by shouldering the cost of training.

Proposed strategic actions

- The capacity challenges revolve around STI training and development, knowledge production, and technological innovation, and partnerships—private–private, private–public, and public–public—are important interventions.
- Institutions of higher learning and research should partner with the African Union, the United Nations, and pan-African organizations such as the African Capacity Building Foundation and the New Partnership for Africa's Development in jointly planning and mobilizing resources for Africa's STI requirements.

Overall Objective 4.

Continuous experimentation for a cyber-physical system enabled through infrastructure and identified software architecture properties and processes.

Strategic Objective 4

Promote physical and digital infrastructural support by state and institutional bodies (e.g., NEPAD-AUDA)

Justification

Access to advanced technology in Africa is constrained by infrastructure parameters. For example, lack of electricity, low tele-density, internet density, and broadband penetration. Accelerating the physical connectivity of fiber-optic networks together with interoperability of virtual platforms is critical; not only for upgrading technology on the continent, but also for reaching and lowering unit costs for the underserved. There is also urgent need to develop strategies for upgrading Africa's ICT infrastructure. More broadly, adequate infrastructural development will drive and sustain economic transformation in Africa, closing the internet connectivity and access gap with advanced economies will enable more African countries to enter the service export markets. Small-scale manufacturers in Africa may also become more competitive with access to digital platforms for research, sales, and distribution.

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Cyber-Physical Systems (CPS) can greatly mitigate the limitations faced by limited access to advanced infrastructure. CPS focus on the integration of computational applications with physical devices, being designed as a network of interacting cyber and physical elements. CPS control and monitor real-world physical infrastructures and thus are having a high impact in industrial automation. As such design, implementation and operation of CPS and management of the resulting automation infrastructure is of key importance for the industry. However, conventionally, control policies are completely separate from the system infrastructure and implemented after manufacturing the system prototype. Such an approach is not feasible to meet the demands expected from CPS because of their complex and dynamic nature. To meet those demands and perform complex control laws, the physical system itself and its dependency relationship with those control laws should be well defined and modeled.

Proposed strategic actions

In Africa, the deficiency in the infrastructure in question is mainly physical assets (machines).

- Establish a steering group to provide CPS strategic direction for funding agencies and that will push for recognition of CPS as a critical priority for government investment.
- To counter this weakness, digital versions of the machine developed and hosted in cyber space and moreover, copies of the digital version can be created and made accessible to a far greater reach compared to the physical assets.
- Furthermore, technologies such as Virtual Reality can be explored to further bridge the gap between the physical and digital by creating an as immersive experience as that can be achieved with physical assets.

Overall Objective 5.

Integrate measurement learning and reporting frameworks into the A4IR strategy for the purpose of managing effectively for results, enhanced coordination and information dissemination in Africa.

Specific Objective 5

Strengthen state and institutional capacity for researching, monitoring and evaluating, and learning from operationalization of the A4IR Standardization Strategy.

Justification

This is essential for tracking, reporting, and learning about the strategy's successes and challenges as well as potential for realizing short-term, medium-term, and long-term desired results over the strategy period.

A first step toward development of state and institutional capacity for research and monitoring and evaluation for the A4IR Standardization Strategy is the implementation of the relevant organizational needs assessment. However, there is limited and relative fragmentation of knowledge about capacity building support for research and research uptake in the African region. In light of these limitations and in particular given the unevenness of available information, it is difficult to map the field with sufficient accuracy to make robust recommendations.

There is a growing level of coordination and collaboration among development research donors with respect to support for research capacity building, particularly in the form of jointly-funded intermediary organizations

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and thematic research networks. However, there is still much room for improvement, especially given very high capacity strengthening needs in Africa and still relatively limited funding.

Proposed strategic actions

- A first step would be for the relevant organizations to support better data collection and communication about research capacity strengthening work, in order to develop a more accurate picture of the research capacity support environment. Ideally, this would start from the bottom up, i.e., through the prism of what type of harmonization and coordination would serve beneficiary organizations most.
- Conduct needs assessment to determine the gaps that are preventing A4IR Standardization Strategy from reaching its desired goals and focus its resources. This could be as simple as agreeing on shared reporting procedures for all participating organizations involved in standards development. Such organizations would be required to get together at the local level to carry out systematic needs assessments to determine organization's needs.

10. MEASUREMENT FRAMEWORK AND APPROACH

There is a common saying that what gets measured gets done. The A4IRSS seeks to propose activities and resources towards achieving its goals and objectives as articulated previously. Theory of Change (ToC) is an approach that considers all aspects of project implementation from inputs to potential and actual impact. All the resources, activities, and immediate, intermediate and long-term results are consolidated together into a diagram for easy access and understanding. ToC assumes that change is not a linear process, but rather it is dependent on inflows, out flows of efforts, and outputs known as change pathways. These pathways result in changes that are either progressive leading to planned outcomes, or retrogressive and requiring refinement of activities and approach to enhance opportunity for positive outcomes. ToC also identifies change drivers that influence achievement of results. These may be individuals, institutions, policies or global events that either present a challenge, an opportunity or both. Therefore, risks and assumptions are central to the approach and should be well considered in advance and assessed periodically. ToC is considered a living document as it is influenced by actual experience with project implementation and needs to be updated periodically to reflect the reality on the ground.

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11. THEORY OF CHANGE

The Theory of Change diagram visualizes the results chain and incremental changes expected of the A4IRSS over the period. The A4IR intervention aims to identify standardization strategies and gaps through institutional coordination of the A4IR Strategy. For the desired results to be achieved, certain change drivers, assumptions, risk factors, and mitigation strategies must be considered to enable success of the strategy. See FIGURE 3.

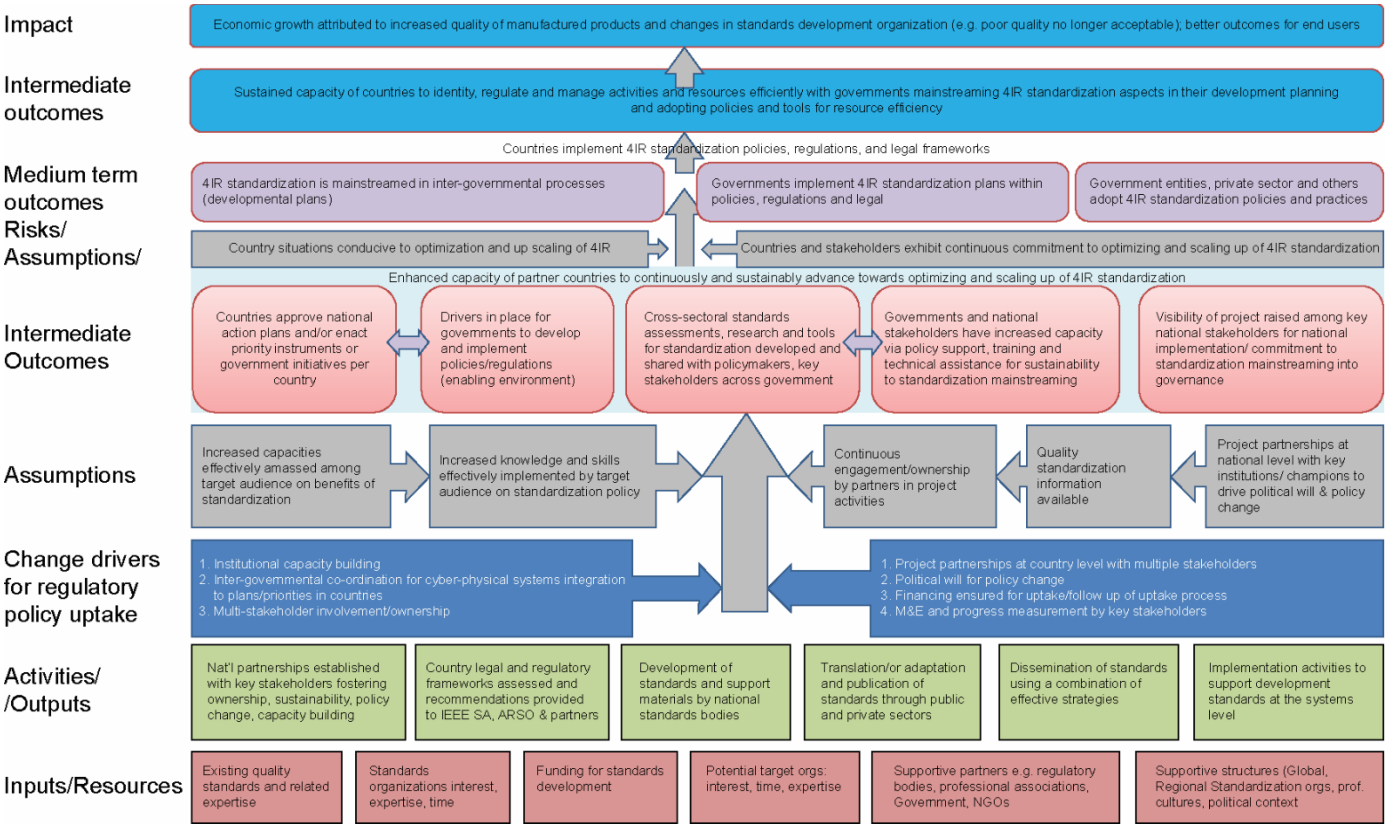

FIGURE 3 Theory of Change Africa Fourth Industrial Revolution Standardization Strategy

The goal of this ToC is to achieve harnessed potential of technology to realize the 4th African Industrial Revolution's Standardization objectives, digital interoperability and cyber-physical systems experimentation through harmonized policies, frameworks, and voluntary standards; economic transformation through increased trade; and harmonized capacity building and enhanced African representation in global standardization and technology governance environments. This ToC focuses on the role of Theory of Change processes in achieving this recognizing that other aspects, such as adequate financing and good project management, are also essential but complementary activities achieved through other pathways. In general, three outcomes related to project design that will drive better impact are: enhanced capacity of partner countries to continuously and sustainably advance towards optimizing and scaling up 4IR standardization; countries implement 4IR standardization policies, regulations, and legal frameworks; and sustained capacity of countries to identity, regulate, and manage activities and resources efficiently, resulting in the following four causal pathways, regarded as necessary and sufficient with respect to Theory of Change:

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a) Strategically, systematically thinking through the logic of an intervention produces a better intervention design, and that this may be enhanced by identifying existing quality standards and related experts, standards development organizations, funding sources to help support the standards development, supportive partners such as regulatory bodies, and supportive structures (global, regional standardization organizations).

b) It is necessary to engage partners/stakeholders that would foment national ownership, sustainability, policy change, and capacity building. The stakeholders should be able to understand how the standardization strategy is likely to play out in their context. Outside the pathway, there is still a need for strong project management skills and sources of finance. All these will require political will for policy change. In terms of enhanced capacity of partner countries to continuously and sustainably advance towards optimizing and scaling up of 4IR standardization, target countries should approve national action and have an enabling environment. This pathway is dependent on drivers being in place for governments to develop and implement relevant policies/regulations.

c) As regards measurement, cross-sectoral standards assessment, research and tools for standardization will improve the value of the monitoring and learning outcomes about the intervention.

d) It is believed the Theory of Change process can be useful to disseminate standards using effective strategies to those not originally involved in its development.

Assumptions: Key assumptions in this logic include that increased capacities effectively amassed among target audience on benefits of standardization; increased knowledge and skills effectively implemented by target audience on standardization policy; there is continuous engagement/ownership in project activities; quality standardization information available; project partnerships at country level and with key institutions/policy champions to drive political will be necessary for policy change; country situations are conducive to optimization and up-skilling of 4IR standardization; and countries and stakeholders exhibit continuous commitment to optimizing and scaling up of 4IR standardization. These should be tested through monitoring across intervention portfolios.

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12. DRIVERS, RISKS, ASSUMPTIONS, AND MITIGATION STRATEGIES

12.1. DRIVERS OF CHANGE

Drivers of change are as follows:

- Focus on minimal acceptable 4IR standards for Africa that will not compromise on quality.
- African benchmark- as outputs of the strategy such as guidelines with minimum standards for the continent or an A4IR framework.

12.2. KEY ASSUMPTIONS

Key assumptions are as follows:

- All organizations want to be part of the 4th Industrial Revolution.
- Africa is interested in being a strategic player contributing to global industry standards bodies.
- Africa needs a common understanding and approach towards A4IR Standards, a harmonized single framework for standards.
- Increased capacities effectively amassed among target audience on benefits of standardization.
- Increased knowledge and skills effectively implemented by target audience on standardization policy.
- There is continuous engagement/ownership in project activities; quality standardization information available.
- Project partnerships at country level and with key institutions/policy champions to drive political will be necessary for policy change.
- Country situations are conducive to optimization and up-skilling of 4IR standardization.
- Countries and stakeholders exhibit continuous commitment to optimizing and scaling up of 4IR standardization. These should be tested through monitoring across intervention portfolios.

12.3. RISKS

12.3.1. COMPETITION VS COOPERATION

- Many standards strategies are already in existence at national level in some countries (for example in artificial Intelligence—Egypt and South Africa).
  1) These activities are however fragmented and not harmonized.
  2) Smaller countries may view standards developed in more economically or technologically advanced African countries as a threat and be slow or unwilling to adopt them.

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12.3.2. TIMELINESS

- A4IR is an emerging area, the pressure of timeliness given the infancy on the continent are key.
  1) 55 African countries may not harmonize quickly enough undermining standardization efforts.
  2) The developed world may otherwise outpace the African continent introducing unfair competition in the single market.

12.3.3. MISAPPLICATION

- Potential for harm for example in the health sector from below standard and counterfeit products entering the single market. This can be mitigated by providing minimum final guarantee to customers against cheap counterfeit goods.

12.3.4. INTERFERENCE

- Nations may still want to exert influence and pressure on technical regulations.
- Security risks—without minimum standards Africa cannot secure its products or services, posing a threat to industry.

12.4. MITIGATION STRATEGIES PROPOSED SO FAR

12.4.1. VIRTUAL COMMISSIONING

This should involve continental advocacy and awareness-raising on 4IR within all African countries. Mobilization is needed to increase understanding about the intention of A4IR.

12.4.2. OUTCOME STRATEGY MAP

Outcome mapping is an approach to measurement that assumes that behavioral changes influence the level of success of development interventions. This is applicable to the A4IR because technology is people centered and dependent for enhancing productivity and adoption, with this in mind, standards organizations, standards developers, research, policy/regulatory, technology producers, and software developers need to consider their contribution to the success of the A4IR strategy on three dimensions. The context and environment within which partners operate in Africa must also be considered and relevant activities designed to enhance opportunity for impact. This applies to individual users and innovators as well and is summarized as an example in TABLE 2.

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TABLE 2 A4IR Strategy Map

	Causal	Persuasive	Supportive
Individual Partners	What will be done to produce an immediate output?	What capacity/ies need to be built among the partners to create new thinking and new ways of doing things?	How will sustained support, guidance, and mentoring be provided?
Partner's Environment	What actions need to be taken to change the policy and regulatory environment under which partners operate?	What will be done to create wider access to information or standardization to ensure inclusivity and dissemination of information and sharing of technology standards?	What networks or relationships will be established, utilized, promoted, or created to ensure achievement of results?

Source: Adapted from Strategy Maps Outcome Mapping: Building Learning and Reflection into Development Programs (2001) by Sarah Earl, Fred Carden, and Terry Smutylo [6].

13. CONCLUSION

In conclusion, central to the A4IR Standardization Strategy are the following:

- Balanced standardization policies and collaboration between state and non-state actors.
- Balanced data policies; capacity building and skill development to enhance productivity.
- Continuous experimentation for cyber-physical systems.
- Integration of measurements, learning and reporting, and information dissemination.

Successful strategy processes will be dependent on the active engagement of all the relevant organizations and focused leadership to establish a sense of ownership and a will to act. The Strategy is proposed by the A4IR activity participants as a management tool to support coordination and alignment in standards development for the benefit of African societies. Also, it sets a foundation against which organizations can measure progress made towards the goals and objectives set herein. The A4IR Standardization Strategy is presented as the guiding document for developing regional strategic plans to support coordination and alignment among the stakeholders who will support and enable the 4th Industrial Revolution and to ensure they maximize inputs to bring its anticipated benefits to the African continent.

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