

Review

Sustainable and Dynamic Competitiveness Towards Technological Leadership of Industry 4.0: Implications for East African Community

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Abstract: The war to technology and economic power have been the driver for industrialization in most developed countries. The first industrial revolution (industry 1.0) earned millions for textile mill owners while the second industrial revolution (industry 2.0) opened the way for tycoons and captains of industry like John D. Rockefeller, J.P. Morgan and Henry Ford. The third industrial revolution (industry 3.0) engendered technology giants like Apple and Microsoft, and made magnates of men like Steve Jobs and Bill Gates. Now, the race for the fourth industrial revolution (industry 4.0) is on and there is no option, every country whether developed or developing must participate. Many countries have positively responded to industry 4.0 by developing strategic initiatives to strengthen industry 4.0 implementation. Unlocking the country's potential to industry 4.0 has been of interest to researchers in the recent past. However, the extent to which industry 4.0 initiatives being launched globally has never been revealed. Therefore, the present study aimed at exploring industry 4.0 initiatives through comprehensive electronic survey of literature to estimate the extend of its launching in different regions. Inferences were drawn from industry 4.0 initiatives in developed nations to be used as the recommendations for East Africa Community. Results of the survey revealed that 117 industry 4.0 initiatives have been launched in 56 countries worldwide consisting of five regions. The country's percent of industry 4.0 initiatives as per region were: Latin America and the Caribbean (15%), North America (40%), Europe (53%), Asia and Oceania (25%), Middle East and Africa (11%). While the worldwide percent was estimated as 25%. This revealed that the big gap is existing between countries towards the race for industry 4.0.

Keywords: 3D printing, Artificial intelligence, Big Data, Crafting the Future, Digital Strategy 2025, High-Tech Strategy 2025, ICT policy, Industry 4.0, Initiative, Internet of things, Made in China 2025, Make in India, M-Pesa, Public-private partnership, Society 5.0

1. Introduction

The race towards industry 4.0 is on [1], and it is crucial that East African Community (EAC) must participate [2, 3]. Unlike the previous industrial revolutions where Africa was left out, industry 4.0 is fast, disruptive and destructive to all sectors including healthcare, education and finance [4] and thus no option for Africa to escape [5]. For this reason, every country must join the revolution either way [6]. Most importantly, it requires early and strong preparation from every country to be successful. In addition, industry 4.0 is developing at an astounding pace and high speed, while

creating a lot of great opportunities. Therefore, if countries do not get ready, industry 4.0 will increase the visibility of inequalities among them including the companies and people (i.e. the have and have-nots, the skilled and unskilled, the rich and the poor). This depict that attempting to maintain the status quo is not an option for any region or country or company [6, 7].

Germany emerged the first country to put forward the idea of industry 4.0, focusing on engineering excellence to dilate its strengths in engineering and machine building to informatization [8]. While US is the world leader in information technology and it focuses on increasing its strengths to robotization, commonly known as Industrial Internet or industrial internet of things (IIoT). The IIoT involves integration and linking of big data, analytical tools, and wireless networks with physical and industrial equipment [9]. However, nowadays, the concept of industry 4.0 has expanded tremendously and its definition goes beyond smart and connected machines and systems and engineering. Its waves of disruption and destruction are also breakthroughs in areas ranging from gene sequencing to nanotechnology, renewable energy to quantum computing, simulation to 3D printing of objects (buildings to body organs) [10, 11]. Simply put, industry 4.0 is the fusion of disruptive technologies and their interaction across the physical, digital and biological domains making it rudimentarily unique from previous revolutions [12]. In other words, industry 4.0 is an intelligent manufacturing, digitalization, automation and robotization as well as e-commercialization of the economy [2, 13–15]. Its wave of disruptive transformations include digital transformation, circular economy and bio-based system, each of which will occur at different periods [16]. A number of countries are apparently embracing digital transformation and thus the first transformational wave of industry 4.0. The main characteristics of industry 4.0 include interoperability, visualization, decentralization, real-time capability, service orientation, modularity, convergence, cost reduction, efficiency and mass customization [17].

Industry 4.0 is a collective term for disruptive technologies and concepts of value chain organization [18], and wave of disruptions and uncertainties with a core of industrial transformation, revitalization and development [19]. This has escalated global competitions among developed and developing countries. Therefore, one of the survival strategies is for the governments to establish critical government programs that can drastically change the global structures of major industrial sectors [20]. This is because industrialization remains emblematic to long-term development ambition for developing and least developed countries, and it is indispensable for competitiveness [21, 22]. However, the wealthy or developed countries view industrialization at different angles, they are doing it intelligently through public policies that promote innovation [22]. For instance, three approaches used by the leading manufacturing nations toward adaptation of industry 4.0 has been revealed [23, 24]. These approaches were labeled as “managed” for China, “coordinated” for Germany [25], and “market-driven” for United States to reflect the government’s role towards industry 4.0 adaptation in a country [22, 26]. Because there is no set formula or single ‘scheme’ for the implementation of industry 4.0 technologies, companies are generally adopting industry 4.0 technologies specific to the requirements of their businesses [27, 28].

Despite the enormous negative impacts of industry 4.0 on almost everything, there are numerous benefits that come with its adoption. For instance, the benefits identified to change the fundamental equation of manufacturing can be classified into six categories: competitiveness, productivity, profitability, revenue, traceability and record-keeping [1]. Competition has reached unprecedented phases globally and the industrial structure is rapidly changing with important foreign investments, including those of emerging economies in Europe, US and China [16, 29]. In the current competition dilemma, it is not just a matter of being a winner but also maintaining a leadership position through clear focus and coordinated efforts to invest in industry 4.0 technologies [30–32]. In addition, organizations or policy makers should think strategically when determining where to focus and invest, so as to build their capabilities in manufacturing [33, 34]. Furthermore, exciting the domestic competitiveness in manufacturing is emblematic to global competitiveness of the country. Therefore, there is dire need for developing new approaches and transformational roadmaps for integrating industry 4.0 infrastructure in small and medium enterprises (SMEs) [35, 36].

Manufacturing landscape today is full of uncertainties with ever-changing demands, greater customization, smaller lot sizes, sudden supply-chain changes and disruptions. It is a complex heterogeneous ecosystem with a wide range of actors, including companies (SMEs), technology and material suppliers, universities, training centres, research and technology organizations, customers and consumers. Therefore, sustainable manufacturing will have to be incorporated with industry 4.0 technologies [37, 38]. Industry 4.0 technologies including Internet of things, Big data and Blockchain [10, 11] are reshaping business dynamic. Consequently, all countries regardless of their levels of development need to align their policies and tools to benefit from these new technologies. Moreover, the rapid convergence of these technologies is not only reshaping production and consumption but also redefining the competitive landscape [39–41]. Innovative manufacturing is a central lineament of industry 4.0 and businesses will need to compete with one another by lowering costs and improving efficiency in the use of technology [42]. The reality is that manufacturing covers a broader range of activities beyond production and therefore, strengthening manufacturing sectors is indispensable for the global sustainable competitiveness [43–45].

As one way to strengthen industry 4.0 deployment and penetration in countries, national strategic initiatives have been launched by the governments or private sectors or public-private partnerships. However, the number of industry 4.0 initiatives that have been launched as well as the number of countries remains unclear. In order to unlock this, the current study was conducted to compare the different industry 4.0 initiatives launched by different countries. In addition, it aimed at identifying industry 4.0 initiatives from developed and developing countries in comparison to the EAC and derive a suitable recommendation to strengthen industry 4.0 adaptation in EAC alongside the existing ICT policy. As industry 4.0 is a convergence of every sector, this paper was intended to reach a large audience including political and corporate leaders, policy makers, academia, industry and the society at large.

2. Methodology

A comprehensive literature search was conducted in electronic databases: Google scholar, Science Direct, Scopus, Sage, Taylor & Francis and Emerald insight from January 2020 to April 2020 following procedures employed by previous studies [10, 46]. The search was performed independently in all the databases and then combined with 'or' and 'and' operators. The multidisciplinary databases included original research peer-reviewed journal articles, books, thesis, dissertations, working papers, white papers, discussion papers, patents and reports covering concepts on industry 4.0 initiatives between 2011 and 2020. Thus, articles in the returned results were assessed concerning their inclusion in this study, and further searches were carried out at the Google search engine using more general search terms to broaden the search, as follows: words "industry 4.0 or fourth industrial revolution", "Industry 4.0 initiative or policy or program or strategy or plan", "industry 4.0 initiative and Germany", "Industry 4.0 initiative and China", "Industry 4.0 initiative and United States", "Industry 4.0 initiative and India", "Industry 4.0 initiative and Mexico", "Industry 4.0 and Japan", "Digital Strategy 2025", "High-Tech Strategy 2025", "Manufacturing USA", "Society 5.0", "Made in China 2025", "Make in India", "Crafting the Future", "East African Community or EAC", "East African Community and industry 4.0 initiative", "Rwanda and industry 4.0 initiative", "Kenya and industry 4.0 initiative", "Uganda and industry 4.0 initiative", "Tanzania and industry 4.0 initiative or United Republic of Tanzania and industry 4.0 initiative", "Burundi and industry 4.0", "South Sudan and industry 4.0" "ICT and Rwanda", "ICT and Kenya", "ICT and Uganda", "ICT and Tanzania or ICT and United Republic of Tanzania", "ICT and Burundi", and "ICT and South Sudan" were used. The last search was done on 10th April 2020. The search outputs were saved on databases and the authors received notification of any new searches meeting the search criteria (from Science Direct, Scopus and Google scholar).

3. Results and Discussion

3.1. Industry 4.0 Initiatives Overview

In the electronic survey, only policies, programs, strategies or plans developed between 2011 to 2020 and focusing on industry 4.0 were considered as industry 4.0 initiatives. The industry 4.0 initiatives launched by identified 56 countries and international cooperation around the world were identified in published literature. The countries were categorized into five regions for the purpose of quantitative analysis. These regions include: (i) Latin America and the Caribbean region has fifteen (15) national industry 4.0 initiatives for seven (7) countries (Table 1); (ii) North America with seven (7) initiatives for two (2) countries as shown in Table 2; (iii) Europe region has forty-one (41) initiatives for twenty-five (25) countries as presented in Table 3; (iv) Asia and Oceania region has thirty-nine (39) initiatives for fourteen (14) countries as shown in Table 4; and (v) Middle East and Africa region has fifteen (15) initiatives for eight (8) countries as presented in Table 5. Besides, Table 6 shows six (6) initiatives for four (4) regional and international cooperation.

Table 1. Industry 4.0 initiatives in Latin America and the Caribbean

S/N	Country	Industry 4.0 initiatives	Year	Funding	Reference (s)
1.	Brazil	New National strategy on industry 4.0 or Industry 4.0 roadmap	2013	Public	[47]
		Brazilian digital strategy (E-Digital) or <i>Brasil Eficiente</i>	2018	Public	[48, 49]
		Working group for I4.0 (WGI4.0)	2017	Public	[21]
2.	Mexico	Prosoft 4.0	2018	Public	[50]
		Crafting the future (CF)	2016	Public-private	[51]
		<i>Nuevo León 4.0</i> (NL4.0)	2018	Public	[52]
3.	Argentina	National innovation	2017	Public	[50]
		Digital industry 4.0 Plan	2018	Public	[50]
		R&D Innovation clusters	2017	Public	[50]
4.	Colombia	Production transformation programme	2016	Public	[50]
		Micro and SMEs Live Digital (<i>MiPyme vive Digital</i>)	2014	Public	[39]
5.	Paraguay	Vision Paraguay 2030	2014	Public	[50]
6.	Dominican Republic	Competitiveness improvement plan	2014	Public	[50]
		SMEs Digital Economy Plan	2015	Public	[50]
7.	Chile	Strategic Programme Smart Industries [<i>Programa Estratégico Industrias Inteligentes</i> , (PEII)]	2015	Public	[21]

Table 2. Industry 4.0 initiatives launched in North America

S/N	Country	Industry 4.0 initiatives	Year	Funding	Reference(s)
1.	US	Smart manufacturing leadership coalition (SMLC) or Smart manufacturing	2012	Public-private	[53–55]
		AMP and 2 nd Advanced Manufacturing Partnership (AMP 2.0)	2012 &	Public- private	[30, 56–58]
		National Network for manufacturing innovation (NNMI) and Manufacturing USA (MUSA)	2012 & 2016	Public-private	[59, 60]

S/N	Country	Industry 4.0 initiatives	Year	Funding	Reference(s)
2.	Canada	Hollings Manufacturing Extension Program (HMEP)	2017	Public	[45, 61-64]
		Industrial Internet Consortium (IIC) or Industrial internet of things.	2014	Private	[65-70]
		<i>Industrie 2030</i>	2016	Public	[71]
		Centre for smart manufacturing (CSM)	2015	Public	[72, 73]

Table 3. Industry 4.0 initiatives launched in Europe

S/N	Country	Industry 4.0 strategic initiatives	Year	Funding	Reference (s)
1.	United Kingdom	High value manufacturing Catapult (HVMC) or Catapult centres	2013	Public	[26]
		Digital academy (DA) or UK digital Strategy	2017	Public	[1]
		National innovation plan (NIP)	2016	Public	[71]
		Innovate UK (Future of manufacturing (FOM))	2013	Public	[71]
2.	France	<i>Industrie du futur</i> (IdF) or <i>alliance pour l'industrie du futur</i> (AIdF) or industry of the future	2015	Public	[25, 74]
		<i>La Nouvelle France industrielle</i> (LNFI) or new France industry (NFI)	2013	Public	[25, 75]
		French Fab (FF) (Made in France)	2017	Public	[26]
		Piano Nazionale Industria 4.0 or Piano Impressa 4.0	2016	Public	[76]
3.	Italy	Intelligent factory clusters (CFI) (<i>Fabbrica intelligente</i>)	2012	Private	[25]
		PRODUCTECH	2015	Public	[25]
5.	Sweden	Made in Sweden 2030	2014	Public	[77]
		<i>Produktion 2030</i>	2013	Public	[25, 78]
6.	Belgium	Made different	2013	Public	[25, 73]
7.	Switzerland	Industry 2025	2015	Public	[9]
8.	Netherlands	Smart Industry	2014	Public	[73, 78]
9.	Finland	Industrial Internet Business Revolution	2015	Public	[79]
		IoT Pilot Factory (IoT PFF),	2017	Public	[79]
		Future industry platform	2015	Public	[80]
11.	Czech Republic	Prumysl 4.0	2013	Public	[25, 80]
		Digital agenda 2020	2015	Public	[81]
12.	Estonia	E-society Estonia	2012	Public	[81]
		Digitization Impulse 2020- Industry of the future	2016	Public	[23]
14.	Latvia	Demola (Riga IT TechHub)	2017	Public	[25]
15.	Denmark	MADE	2012	Public	[25, 79]
16.	Hungary	IPAR 4.0 National Technology Platform/ Irinyi plan	2017	Public	[80]
17.	Bulgaria	Kontseptsia Industria 4.0	2017	Public	[80]
18.	Romania	National strategy for Romania Digital Agenda 2020	2017	Public	[80]
19.	Lithuania	Pramone 4.0	2017	Public	[80]
20.	Austria	TUWin 4.0	2013	Public	[31]
		Platform Industry 4.0	2014	Public	[31]

S/N	Country	Industry 4.0 strategic initiatives	Year	Funding	Reference (s)
		Industry 4.0 Austria	2015	Public	[31]
21.	Slovenia	Slovenia digital coalition/Slovenia Industrial Policy 2013	2013	Public	[80]
22.	Slovakia	Smart industry platform	2016	Public	[25, 80]
23.	Ireland	Ireland's industry 4.0 strategy	2019	Public	[82]
24.	Spain	<i>Industria Conectada 4.0</i>	2017	Public	[25, 71]
		5G Digital Agenda	2018	Public	[39]
25.	Germany	Industrie 4.0 (I4.0) and Plattform Industrie 4.0 (PI4.0)	2011& 2013	Public-private	[38, 83–86]
		Mittelsland 4.0	2012	Public -private	[87, 88]
		Digital Strategy (DS) 2025 and High-Tech Strategy (HTS) 2025	2016& 2018	Public	[87, 89]
		AI Strategy	2018	Public	[87]
		Shaping Digitalization Implementation Strategy for the Federal government (SDISFG)	2018	Public	[87, 90]

Table 4. Industry 4.0 initiatives launched in Asia and Oceania

S/N	Country	Industry 4.0 initiatives	Year	Funding	Reference(s)
1.	China	Made in china 2025 (MIC 2025)	2015	Public	[40, 91]
		Internet plus (+)	2015	Public-Private	[92, 93]
		Belt and Road Initiative (BRI)	2013	Public	[94–98]
		13 th five years Plan (13 th FYP)	2016	Public	[99–102]
2.	Taiwan	Taiwan productivity 4.0	2015	Public	[71]
		Smart machinery	2017	Public	[23]
		Asia Silicon Valley development	2017	Public	[23]
3.	South Korea	Manufacturing innovation (MI) 3.0	2014	Public	[103]
		I-Korea 4.0	2018	Public	[104]
		Innovation Platform Programme (IPP)	2017	Public	[105]
4.	Japan	Industrial Value-chain Initiative (IVI)	2016	Private	[8, 106]
		Revitalization and Robot strategy (Robot revolution initiatives (RRI))	2015	Private-public	[107–114]
		Society 5.0 (5 th science and technology Basic plan), super smart society	2016	Public-Private	[19, 115]
		AI technology Strategic conference (AITSC)	2016	Public	[116]
		IoT Acceleration Consortium (IoTAC)	2015	private	[52]
		Industry 4.1J	2015	Public	[103]
5.	Singapore	Infocomm Media (ICM) 2025	2015	Public	[117, 118]
		RIE 2020 plan (Research, Innovation and Enterprise)	2016	Public	[119]
		Smart nation	2014	Public	[120]
		Service and digital economy Technology roadmap (SDETRM)	2018	Public	[121]

S/N	Country	Industry 4.0 initiatives	Year	Funding	Reference(s)
6.	India	Make in India (MII).	2014	Public	[122, 123]
		Start-up India	2015	Public	[124]
		Digital India (DI)	2014	Public	[125]
		Skill India (SI)	2015	Public	[126]
		Smart India	2015	Public	[124]
7.	Indonesia	Making Indonesia 4.0 (MI 4.0)	2017	Public	[52]
		2020 Go Digital vision	2015	Public	[121]
8.	Russia	National Technology Initiative (NTI)	2015	Public-private	[127]
		Data Economy Russia 2024	2017	Public	[128]
9.	Thailand	Thailand 4.0	2016	Public	[129]
10.	Turkey	Digital conversion association	2016	Public	[51]
11.	Vietnam	Strengthening the country's capacity to address Industry 4.0	2017	Public	[21]
12.	Malaysia	Industry 4WRD or National policy on industry 4.0	2018	Public	[130]
		Eleventh Malaysia plan	2015	Public	[71]
		Comprehensive Automotive Resurgence Strategy programme	2016	Public	[131]
14.	Australia	Industry 4.0 Testlabs	2017	Public-private	[132]
		Industry 4.0 prime minister taskforce	2016	Private	[132]
		The next wave of manufacturing	2013	Pubic	[72]

Table 5. Industry 4.0 initiatives launched in Middle East and Africa

S/N	Country	Industry 4.0 initiatives	Year	Funding	References
1.	Israel	Israel 2028	2018	Public	[81, 133]
		Israel Innovation report 2017	2015	Public	[81, 133]
		Startup Nation	2012	Public	[133, 134]
2.	United Arab Emirates (UAE)	Smart Dubai 2021	2017	Public	[81]
		UAE AI Strategy 2031	2018	Public	[81]
		UAE's National Agenda 2021	2016	Public	[135]
3.	Kingdom of Saudi Arabia (KSA)	Saudi Vision 2030	2016	Public	[135, 136]
		KSA's National Transformation Plan 2020	2016	Public	[135]
		Qatar National Vision 2030	2016	Public	[135]
4.	Qatar	Qatar's National Development Strategy 2017–2022	2017	Public	[135]
		New Kuwait Vision 2035	2016	Public	[135]
		South Africa (SA) Intsimbi programme	2018	Public	[127]
7.	Morocco	Digital development agency (<i>L'Agence de Développement Digital</i>) (ADD)	2017	Public	[137–139]

S/N	Country	Industry 4.0 initiatives	Year	Funding	References
8.	Rwanda	Centre for the Internet of Things (IoT)	2017	Public-Private	[6]

Table 6. Industry 4.0 initiatives for regional and international Cooperation

S/N	Region	Industry 4.0 initiatives	Year	Funding	References
1.	G20	New industrial revolution (NIR)	2014	G20 members	[35, 106]
2.	EU	Factories of the future	2013	EU members	[140, 141]
		Factories 4.0 and beyond	2018	EU members	[140]
3.	BRICS	BRICS Skills development working Group	2018	BRICS members	[6]
		BRICS Digital Cooperation on Industrialization	2019	BRICS members	[142]
4.	GCC	Digital Transformation Agenda	2016	GCC members	[135]

The results of the electronic survey show the number of countries in each region and the total number of industry 4.0 initiatives launched per region as depicted in Table 7. In statistical analysis, the world countries list was adopted from the List of countries prepared by “Population Division of the United Nations Department of Economic and Social Affairs” [143]. The total number of countries in each region alongside those that have launched industry 4.0 initiatives were captured in Table 7. Analysis (Figure 1) illustrates that Europe (53%) has half the numbers of its countries with industry 4.0 initiatives and leads rest of the regions followed by North America (40%), Asia and Oceania region (25%), Latin America and the Caribbean region (15%), and Middle East and Africa (11%). The worldwide percent of countries with industry 4.0 initiatives as 25%.

Evidence from this study shows that European countries are progressing faster than the rest of the regions in adopting industry 4.0. This could be because of the strong international cooperation (European Union) with focalized industry 4.0 policies. As demonstrated, every region as well as country is developing industry 4.0 at their own pace. This is due to the fact that setting up industry 4.0 initiatives and technological developments require huge finances and resources. For this reason, the inequality is very visible among countries and regions as developed nations are not limited with finances unlike developing countries. This is supported by the fact that Europe has more economically and technologically advanced countries than the rest of the regions combined.

Table 7. Industry 4.0 initiatives launched across the globe

S/N	Regions	Number of	Countries with industry 4.0	Number of launched	Country
		Countries	initiative (s)	initiatives	percentage (%)
1.	Latin America and the Caribbean	46	7	15	15
2.	North America	5	2	7	40
3.	Europe	47	25	41	53
4.	Asia and Oceania	55	14	39	25
5.	Middle east and Africa	72	8	15	11
6.	Worldwide (overall)	225	56	117	25

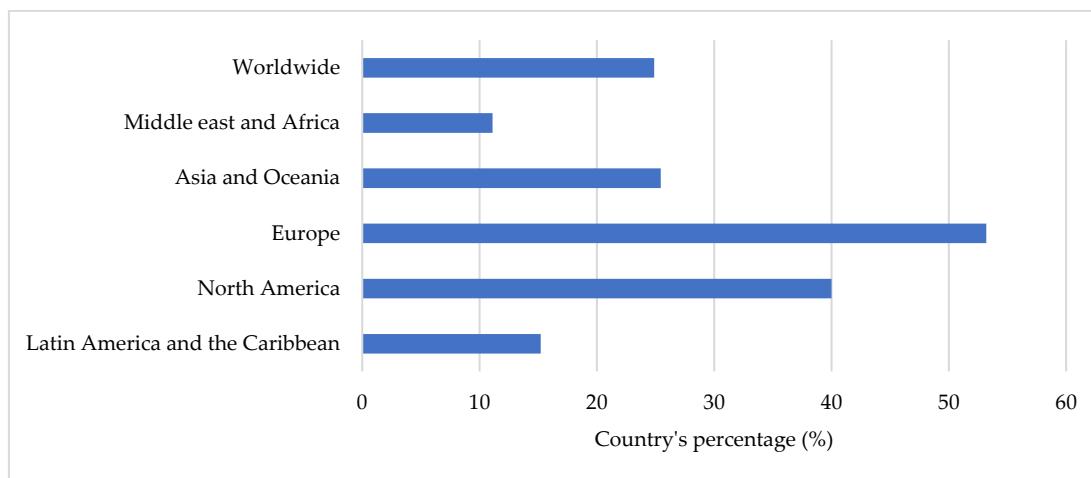


Figure 1. Industry 4.0 initiatives launched in different regions and worldwide

3.2. Comparison of Industry 4.0 Initiatives

Further literature search and study were conducted to understand the differences existing between the different industry 4.0 initiatives that have been launched in different countries. In order to narrow the scope of the literature searches, six countries were selected from which six initiatives were selected and compared in term of their goals and industry 4.0 technologies focus areas. As illustrated in Figure 2, Germany, US, China and Japan were selected because of their outstanding economic and technology powers [88]. While India and Mexico were also selected because of their unprecedented technological leapfrogging in the 21st century. It was quoted that these two countries were able to “jump” directly from industry 2.0 to industry 4.0 [144]. Evidently, it was necessary to compare each of them with the economic power countries. The fact that each country has launched more than one industry 4.0 initiative, only a recently launched initiative in each country was selected for this study. The “digital strategy 2025 and High-Tech strategy 2025 (DS &HTS 2025)” from Germany, “Manufacturing USA (MUSA)” from US, “Made in China 2025 (MIC 2025)” from China, “Society 5.0” from Japan, “make in India” from India and “Crafting the future” from Mexico.

3.2.1. Digital Strategy 2025 and High-Tech Strategy 2025

Digital strategy 2025 and High-Tech strategy 2025 (DS&HTS 2025) are two complementary industry 4.0 programs that have been launched recently. The Digital Strategy 2025 initiative was launched in 2016 under German Federal Ministry for Economic Affairs and Energy (BMWi) [89]. Its central focus is on digitizing everything, including the products [145], and on small and medium scale enterprises (SMEs) to attain a competitive advantage [146]. It also aim at enabling the German economy in responding to new challenges and enhancing its competitiveness both in quality and technology, by combining traditional competitive advantages with the newest technology, modern methods and specific support programmes [89]. Germany was quick to realize their digitization weakness in the industry sectors (automotive, machine tools, chemicals, and pharmaceuticals) over its competitors (US, Japan, China) [147]. This has triggered the launch of Digital strategy 2025 to knead alongside the existing initiatives (*industrie 4.0*, Mittelstand 4.0) so that German economy remain competitive.

Germany launched another initiative called “High-Tech Strategy 2025” in September 2018 as the strategic framework for research and innovation policy [148]. They reasoned that ability to gain sustainable competitiveness is focalized around strengthening education, research and innovation. HTS 2025 aims at scaling-up investment in research and development [148]. It also focuses on leveraging key society challenges namely: healthcare sustainability, climate protection and energy, mobility, urban and rural areas, safety and security, and economy and work 4.0. The intention is to

shape the economy, working life and lifestyles by creating a universal environment for harnessing the competitiveness, the preservation of the natural life-support systems, and social equity [148]. This is quite similar to the goal of Japanese Society 5.0 initiative. However, HTS 2025 is being driven by a mission-oriented approach to bring together the activities of the ministries involved in the fields of action and relevant players from the science and research community, the private sector and civil society. There are 12 mission-oriented approach including combating cancer, creating sustainable circular economies and finding new sources for new knowledge [148].



Figure 2: Industry 4.0 initiatives in the six selected countries

3.2.2. Manufacturing USA

Manufacturing USA (MUSA) formally known as National Network for Manufacturing Innovation (NNMI) is a successful program that has laid down the foundation for American manufacturing competitiveness for generations to come. It is the US Federal Government program for coordinating public, private investments and academia to improve the competitiveness and productivity of US manufacturing through the creation of a robust network of manufacturing innovation institutes, each focused on a specific and promising advanced manufacturing technology area [59]. NNMI was introduced and launched in 2012 in the 2013 Fiscal year (FY) budget by President Barrack Obama which was then renamed as Manufacturing USA on September, 2016 by Secretary of commerce in the FY 2016. It was to raise awareness of the value of the program to industry, academia, nonprofits, the public, and the entire US manufacturing community, recognizing the program's impact on securing America's manufacturing future [60, 149]. The technology focus areas include additive manufacturing, bio-manufacturing, nano-manufacturing, advanced materials, robotics, modeling and simulation, and real-time optimized production (smart manufacturing) [150]. Manufacturing USA program is a network of 14 manufacturing institutes which are operational and implementing activities in their technology areas with each institute funded by a unique public-private partnership as shown in **Table 8** [59, 151, 152].

Table 8. Manufacturing USA Institutes and the Technology areas.

S/N	Technology	Institutes	References
1.	Additive manufacturing	American Makes: the national additive manufacturing institute	[153-155] [156]
2.	Digital manufacturing and design	DMDII: Digital manufacturing and design institute or MxD: Manufacturing times digital	[157]
3.	Lightweight metals manufacturing	LIFT: Lightweight innovation for tomorrow	[158, 159]
4.	Wide bandgap power electronics manufacturing	PowerAmerica: the next generation of power electronics manufacturing innovation institute	[160]
5.	Fiber-reinforced polymer composites	IACMI: Institute for advanced composite manufacturing institute	[161]
6.	Integrated photonics manufacturing	AIM photonics: American institute for manufacturing integrated photonics	[162, 163]
7.	Manufacturing thin flexible electronics devices and sensors	NextFlex: America's flexible hybrid electronics manufacturing institute	[164]
8.	Fiber materials and manufacturing process	AFFOA: Advanced functional fabric of America institute	[165, 166]
9.	Smart manufacturing	CESMII: Clean energy smart manufacturing innovation institute	[167, 168]
10.	Biofabrication and manufacturing	BioFabUSA: Advanced regenerative manufacturing institute (ARMI)	[169]
11.	Robotic manufacturing	ARM: Advanced robotics for manufacturing institute	[170]
12.	Biopharmaceutical manufacturing	NIIBML: National institute for innovation in manufacturing biopharmaceuticals	[171]
13.	Molecular chemical process intensification for clean manufacturing	RAPID: Rapid advancement in process intensification deployment institute	[172]
14.	Sustainable reduction carbon emission and manufacturing with clean energy	REMADE: Reducing Embodied-energy and Decreasing Emissions	[173, 174]

3.2.3. Made in China 2025

Made in China 2025 (MIC 2025) is a national strategy of industry 4.0, announced by China's State Council in May 2015 [91, 175]. The goal of MIC 2025 is to comprehensively upgrade, consolidate and balance China's manufacturing industry, turning it into a global leader in innovation and manufacturing [176]. This will be achieved in three stages of strategic plans: (i) transforming China into major a manufacturing power by 2025; (ii) reaching an intermediate level among world's manufacturing powers by 2035; and (iii) becoming the leader among the world's manufacturing powers by 2049 [177]. MIC 2025 is to some extend inspired by Germany's Industry 4.0 with reference to the inclusion of Small and Medium Sized Enterprises (SMEs) in the supply chain, and extensive use of new information technologies. MIC 2025 accentuates terms like "indigenous innovations" and "self-sufficiency" which aggressively intends to increase the domestic market share of Chinese suppliers for basic core components and valuable materials by the year 2025 [178]. Thus, it imposes devastating fear of distorting global markets and negatively affect US and Germany [179]. MIC 2025 focuses on ten industrial sectors namely: (i) Advanced marine equipment and high-tech vessels; (ii)

Advanced rail and equipment; (iii) Agricultural machinery and technology; (iv) Aviation and aerospace equipment; (v) Biopharmaceuticals and high-end medical equipment; (vi) Integrated circuits and new IT technology; (vii) High-end electronic equipment; (viii) High-end manufacturing control machinery and robotics; (ix) Low and new-energy vehicles; (x) New and advanced materials [177]. The key focused industry 4.0 technologies for MIC2025 include Cyber physical system, Internet of things, Cloud computing, Big Data, Artificial intelligence and Robotics [52].

3.2.4. Society 5.0

Society 5.0 or super smart society was officially coined in the 5th Science and Technology Basic Plan in FY2016-FY2020 by the Japanese's Council for Science, Technology and Innovation which was affirmed by a Cabinet choice in January 2016 [115]. Society 5.0 aims to provide a common societal infrastructure for prosperity based on an advanced service platform [180]. It also aims to realize a society where people enjoy life to the fullest. The society 5.0 is not only for prosperity of Japan but also countries worldwide [19]. In addition, Society 5.0 aims to create a cyber-physical society in which citizens' daily lives will be enhanced through increasingly close collaboration with artificially intelligent systems forming a super smart cyber physical system [181, 182]. The Society 5.0 advertises to the new monetary society following the seeker gatherer (Society 1.0), peaceful agrarian (Society 2.0), modern social order (Society 3.0), and data social orders (Society 4.0) [180]. The main technology focus areas of Society 5.0 are [52]; Cyber physical systems, Internet of things, Cyber Security, Cloud computing, Big Data, Artificial intelligence and Smart services/Smart city.

3.2.5. Make in India

Make in India was initiated and launched in September 2014 by the Indian President as an initiative with the goal of positioning India in a forefront of the global manufacturing and design. It is a measure taken by the government of India to strengthen and improve competitiveness in the manufacturing sector by creating competitively priced and quality products [144]. Make in India initiative aims to aggressively transform India into a manufacturing and technology hub. The prioritization of manufacturing sector by this initiative was done after garnered considerable attention from all industry sectors which was based on the fact that manufacturing sector of any economy is one of the key drivers of its employment and growth [124]. The key focus areas of the initiative includes increased foreign direct investment (FDI) in manufacturing, minimize reliance on imports, enhance job opportunities, expand infrastructure and promote technological evolution [144]. Its technology focus areas include industrial mobility, cloud platform, Big-Data analytics and industrial cyber Security. With these technologies India aims to achieve the best practices and strengthen India's competitiveness in 25 industry sectors including automobile, defense, aviation, biotechnology, chemicals, electrical machinery, electronics, food processing, oil and gas, and pharmaceuticals [122].

3.2.6. Crafting the Future

Crafting the future is the strategic initiative of industry 4.0 of Mexico founded in 2016 with partnership from government entities (science and academia), Companies (Intel, Continental automotive, Honeywell, the Volkswagen Group) and trade associations [51]. Mexico is well-known for its cost competitiveness advantage (i.e., low-cost labour force and high-volume production) that has made it become a world-class manufacturing hub [71]. With its industry 4.0 initiatives, Mexico aspires to be competitive with technological advanced manufacturing super power countries (UK, Germany, US, etc.). Crafting the future initiative focuses on the key industry 4.0 technologies which include Internet of things, Big Data, Cloud Computing, System integration, Collaborative robots, Modeling and Simulation [51]. These strategies focus on establishing smart factories in the production process via technological advancements which prioritizes the main industry sectors: chemical industry, aerospace economy, automotive industry, space industry, energy sector and logistics [52].

Generally, Crafting the future initiative has similar goal of attaining competitiveness as the rest of the initiatives. Both industry 4.0 initiatives focus on boosting domestic manufacturing and strengthening the SMEs with use of industry 4.0 technologies. The visible different that exist between the industry 4.0 initiatives is mainly on the technology focus areas. Each initiative has different technology focus areas except for “Digital strategy and High-Tech Strategy 2025” which have no technology focus areas. These initiatives focus on all technology areas because they are mainly research and development (R&D)-based initiatives. The industry 4.0 technologies adopted by each initiative are shown in Table 9.

Table 9. Technology focus of industry 4.0 initiatives

Technology	DS&HTS 2025	MUSA	MIC2025	Society 5.0	Made in India	CF
IoT	○	○	✓	○	✓	✓
Big Data	○	○	✓	✓	✓	✓
3D printing	○	✓	○	○	○	○
Cloud computing	○	○	✓	✓	✓	✓
AI	○	○	✓	✓	○	○
CPS	○	○	✓	✓	○	○
Robots	○	○	✓	○	○	✓
Modeling and simulation	○	✓	✓	○	○	✓
Nanotechnology	○	✓	○	○	○	○
Smart services	○	○	○	✓	○	○
Smart factory	○	✓	○	○	○	○
Mobile devices	○		○	○	✓	○
Biotechnology	○	✓	○	○	○	○
Cyber security	○	○	○	✓	✓	○
Advanced materials	○	✓	○	○	○	○
System integration	○	○	○	○	○	✓

AI-Artificial Intelligence, CPS-Cyber Physical System, IoT-Internet of Things

3.3. East African Community on Industry 4.0

3.3.1. Definition of the East African Community

The East African Community (EAC) is the regional intergovernmental organization of the Republics of Kenya, Uganda, Rwanda, Burundi, South Sudan and the United Republic of Tanzania (URT) with its headquarters in Arusha, URT. The EAC treaty was signed on 30th November 1999 and enacted on 7th July 2000 [183–185]. The main objective of the EAC is to introduce policies and programs to promote cooperation among its member states for mutual benefits in a wide range of areas including political, economic, social, cultural affairs, research and technology, defense, security, legal and judicial affairs [186].

The EAC has strongly established a number of autonomous institutions including the East African Development Bank (EAfDB) and the Inter-University Council of East Africa (IUCEA). Both the EAfDB and IUCEA are headquartered in Kampala, Uganda. The EAfDB is mainly involved in the cross-border financing of regional development programmes and projects, small and medium scale industries. IUCEA serves to facilitate contact between the universities of East Africa, to provide a forum for discussion on a wide range of academic and other matters relating to higher education, and to help maintain high and comparable academic standards in the universities of East Africa. The EAC vision is to become a globally competitive upper-middle income region by 2050. This vision

is the overall for its State Partners, while each has its own vision as shown in Table 10 [185]. The availability of autonomous institutions and Strategic visions are the strong assets for EAC with some capabilities of supporting the race towards industry 4.0.

Table 10: Strategic vision of the EAC's partner states

Partner State	Time frame	Strategic Vision	References
Uganda	Vision 2040	Transform Ugandan society from peasant to a modern prosperous country	[187]
Kenya	Vision 2030	Globally competitive and prosperous Kenya with a high quality of life	[188]
Rwanda	Vision 2020, and	Become a middle-income country by 2020	[189]
	Vision 2050	High standard of living	[190]
United Republic of Tanzania	Vision 2025	High quality of life anchored on peace, stability, unity, and good governance, rule of law, resilient economy and competitiveness	[191]
South Sudan	Vision 2040	Realizing freedom, equality, justice, peace and prosperity for all	[192]
Burundi	Vision 2025	Sustainable peace and stability and achievement of global development commitments in line Millennium development goals	[193]
EAC	Vision 2050	Attain a prosperous, competitive, secure and politically united East Africa	[184]

3.3.2. Industry 4.0 Potential in EAC

The six major disruptive industry 4.0 technologies for Africa include Artificial Intelligence (AI), the Internet of Things (IoT), Big Data, 3D printing, blockchain and drones [6]. These are being utilized in five main domains: agriculture, energy, industry, regional integration and wellbeing [6]. The Industry 4.0 adoption by EAC depends majorly on continental effort. At the African level, the preparedness to industry 4.0 can be witnessed from the launched industry 4.0 initiatives including "EU-AU Digital Task force", "Smart Africa" and "One Africa Network". Smart Africa is the program that EAC is actively involved in. It was initiated and launched in 2013 by seven African Heads of State (Rwanda, Kenya, Uganda, South Sudan, Mali, Gabon and Burkina Faso). At the EAC level, "One Network Area (ONA) roaming initiative" was initiated under the Northern Corridor Agreement. This could create an impetus environment for industry 4.0 technology in EAC. At country level, only Rwanda has shown up while the rest like Kenya and Uganda have well-demonstrated their potential with very strong ICT policies [6].

Rwanda. It is one of the three Africa countries (others being South Africa and Morocco) that have started developing industry 4.0 strategies alongside their ICT policies or created technology centre [138, 194]. The government of Rwanda has setup a "Centre for the Internet of Things (IoT)" in partnership with Inmarsat, the provider of global mobile satellite communications [6]. Centre for the Internet of Things (IoT) initiative aims to facilitate students' learning, to develop IoT prototypes and to carry out academic research in the field of potential IoT solutions. Further, it strives to accelerate the deployment of the IoT and smart city solutions. Within the ICT policy directed by SMART Rwanda Master Plan 2015–2020, there are initiatives that have been launched by both the Rwandese government and private sectors. The major ICT innovative initiatives include IREMBO platform,

Digital Ambassadors Program, Kigali Innovation City and Rwanda's ICT Hub Strategy 2024. The ICT policy has greatly developed Rwanda's cultural and creative industry to the extent of becoming a global economy [195]. However, manufacturing sectors have not yet been fully revived for the country to harvest its goal of competitiveness in the vision 2020 [196–198]. The new policy called "Made in Rwanda" is a holistic roadmap aimed at increasing economic competitiveness by enhancing Rwanda's domestic market through value chain development. It is aligned with Rwanda's aspiration to become an upper middle income country by 2035 and higher income by 2050 [199]. This new policy has the capacity to strategized and promote industry 4.0 implementation in the country.

Kenya. It is one of the African countries that have attained a lower-middle income status [186]. In the digital world, Kenya has been monikered as the Africa's "Silicon Savanah" [200, 201]. This has been due to the existence of a very strong focalized ICT policy underlined with its Vision 2030. In addition, technology in mobile money system such as M-Pesa is unprecedented [202]. The M-Pesa revolution has shaped Kenya's digital space and placed Kenya ahead of other developing economies in the region in the deployment and use of digital technology [203, 204]. M-Pesa is a mobile payment platform launched in 2007 as a partnership between Safaricom (telecommunication (telco) company), Commercial Bank of Africa and Commercial Banks in Kenya [205]. Another incredible turning point following M-Pesa revolution was the launch of a virtual savings platform called "M-Shwari" and has been replicated across EAC, with "M-Pawa" in United Republic of Tanzania (URT) and "Mokash" in Uganda and Rwanda. Similarly, KCB M-Pesa and Equitel for mobile banking were launched [205]. Within the ICT policy, a Government Digital Payments Taskforce known as eCitizen was launched. Other ICT innovative platforms include Drumnet, mFarm and Ushahidi [188, 206]. Despite the strong ICT policy in the country [207], Kenya's roadmap to industry 4.0 has remained unclear. Recently, Kenya Association of Manufacturing (KAM) have proposed an Agenda for securing the future of Manufacturing Industry in Kenya on industry 4.0 and aim to develop a national policy framework and programme to implement industry 4.0 with sectoral bias [208]. This is still just on the paper work which will need to be implemented to show Kenya's readiness to industry 4.0. Another strong asset of Kenya is vitally dependent on the heavy investment in renewable energy both in wind and geothermal power projects [208]. This create a very strong avenue for industry 4.0 deployment and implementation as energy 4.0 is centered around renewable energy.

Uganda. It has a strategic Vision 2040 where industrialization is the priority. In contrast, the country came out with a national industrial policy which does not prioritize manufacturing. This made manufacturing sector less competitive by focusing on mainly agro-processing and low-value manufacturing [209–211]. Yet high-value manufacturing is the core for industrialization in most developing countries [209]. This is the reason why Uganda have not yielded positive results for industrialization in the past years [212]. The government of Uganda with a great potential has committed the country to developing a digital vision for Uganda known as Digital Uganda Vision (DUV). The DUV provides an overarching framework that responds to the Vision 2040 by providing a unified ICT policy direction [213]. The ICT Policy driven by Vision 2040 is spearheaded by the Ministry of ICT which was purposely established to ensure growth and deployment of ICT in Uganda. Under the Ministry of ICT, there are several discussions being made on Industry 4.0 from the policy viewpoint. In addition, the ICT officers are being trained on industry 4.0 technologies covering wide-ranging fields such as Artificial Intelligence (AI), Big Data, Blockchain Technologies and Cloud Computing. Moreover, the Block-chain Association of Uganda has already been founded and Nakawa Innovation Centre has been established [214]. This show some sort of readiness to embrace industry 4.0, although there is still much to be done by Uganda to welcome this industrial revolution monster.

United Republic of Tanzania (URT). This country, on the other hand is improving productivity and competitiveness of its industrial sector which is directed by 5th Phase Government plan under the URT's Vision 2025 [215, 216]. The country have a strong ICT policy thought not much have been reported on it [217]. However, the potential positive impacts of ICT are mainly in large-scale agriculture, and firm's business processes [218]. One of the strongest assets of URT is its ability to accommodate the concept of sustainability by going for more advanced and green technology, hence

achieving increase in its productivity [219]. In addition, Centre of excellence in ICT for East Africa (CENIT@EA) has been launched. It aims at providing relevant skills, capacities and knowledge to shape the digital transformation. CENIT@EA is a consortium between URT's University and German Universities and was launched in 2018 [220]. This strong collaboration is very importance for setting up profound requisite digital skills and thus eventually lay good environment for industry 4.0 implementation.

Burundi and South Sudan. These two EAC member countries have failed to performed in both economies and digital revolution due to unstable political weather of the countries which contributed to chronic poverty [186, 221, 222]. As a result of their developmental Visions majorly aimed at restoring peace and stability, they are the least competitive in the EAC and Africa at large [223]. These countries are yet to setup strong ICT policies to enable them start thinking about the disruptive industrial revolution. In addition, resources, finances and skill workforce are vitally needed for industry 4.0 adaptation. Therefore, these countries need a lot of assistance from the international funding bodies to foster their readiness to industry 4.0.

3.3.3. Comparison of the EAC State Partners

All the EAC members have strong ICT policy except Burundi and South Sudan. These two have limited studies about them and they were excluded from the comparative study. Kenya and Rwanda are leading on ICT deployment. However, Rwanda is currently developing many new ICT innovative initiatives with the capabilities to harvest the competitiveness. Importantly, full exploitation of ICT potential in a country is instrumental regarding the realization of industry 4.0. However, the applications of ICT have been mainly centered around governance and services in each country as shown in Table 11.

Table 11. Initiatives in EAC launched within the ICT policies

Country	Initiatives	Year	Funding	Reference (s)
Uganda	ICT4Agric	2017	-	[224]
	e-government (eTAX, mTrac, e-water)	-	Public	[225, 226]
	Mobile money platform (MTN, Airtel)	2009	Public-private	[227]
Kenya	M-Pesa	2007	Private	[205]
	M-Shwari, M-Pawa and Mokasa	2012	Private	[228, 229]
	Government Digital Payments Taskforce (eCitizen) or e-government	-	Public	[230, 231]
	PRIMR (Primary Math and Reading)	2011	Public-Private	[232]
	ICT4D or e-government agency	-	Public	[233, 234]
URT	e-Transparency	2009	Public	[235]
	E-government strategy 2013	2013	public	[236]
	IREMBO e-government platform, one-stop e-government	2015	Public-Private	[237-239]
Rwanda	Digital Ambassadors Program (DAP)	2019	Public	[240]
	Kigali Innovation City (KIC)	2016	Public	[241, 242]
	Rwanda's ICT Hub Strategy 2024	2019	Public	[243]
	Tap&Go Smartcard	2015	Public-Private	[237]
	Smart city Rwanda	2019	Public	[244]

On the side of industry 4.0 initiative, EAC member countries have shown daunting preparedness with exception of Rwanda. While on the other side of industry 4.0 technologies application, Majority are performing well. The analysis of industry 4.0 technologies applications and startups was based on the study "unlocking the African potential for the fourth industrial revolution" [6]. Evidence of the list of industry 4.0 technologies currently being applied in industrial sectors and number of their

startups shows Kenya has the highest followed by Rwanda, Uganda and then URT. Table 12 and Table 13 illustrate the current state of industry 4.0 technologies applications and the start-ups as per the year 2019 respectively.

Table 12. Application of industry 4.0 technologies in industrial sectors of EAC

Industrial sector	Uganda	Kenya	URT	Rwanda
Agriculture	✓ Big Data	✓ AI	✓ Drones	✓ Big Data
	✓ IBS	✓ Big Data	✓ IoT	✓ IBS
	✓ IoT	✓ Drones		✓ IoT
		✓ IBS		
		✓ MS		
		✓ IoT		
		✓ Robots		
	✓ AI	✓ IBS	✓ Drones	✓ AI
	✓ Big data	✓ MS		✓ Drones
	✓ IoT	✓ IoT		✓ IBS
Healthcare				✓ MS
				✓ IoT
Industry	○ N/A	✓ IBS	○ N/A	✓ Drones
		✓ 3D printing		
Energy	✓ MS	✓ MS	✓ IoT	✓ IoT
	✓ IoT	✓ IoT		
Education	✓ IBS	✓ AI	✓ IBS	✓ Big data
	✓ IoT	✓ Big data	✓ IoT	✓ IoT
	✓ Robots	✓ IBS		
		✓ MS		
		✓ IoT		
	✓ IoT	✓ Drones	✓ Drones	✓ Drones
	✓ Drones			
	✓ IoT	✓ Blockchain	✓ Blockchain	✓ Blockchain
	✓ MS	✓ Big Data	✓ IoT	✓ Big Data
	✓ IBS	✓ IoT	✓ 3D printing	✓ MS
Crosscutting		✓ 3D printing	✓ MS	✓ IBS
		✓ MS	✓ IBS	
		✓ IBS		
MSFI	✓ IoT	✓ Drones	✓ Drones	✓ Drones
	✓ Drones			
	✓ IoT	✓ Blockchain	✓ Blockchain	✓ Blockchain
	✓ MS	✓ Big Data	✓ IoT	✓ Big Data
	✓ IBS	✓ IoT	✓ 3D printing	✓ MS
		✓ 3D printing	✓ MS	✓ IBS
		✓ MS	✓ IBS	
		✓ IBS		

IBS-Internet-based services, IoT-Internet of Things, AI-Artificial intelligences, MS-Mobile services, N/A-Not available.

MSFI-Modernized Services and Financial Inclusion.

Table 13. Industry 4.0 technologies with startups in EAC

Technology	Uganda	Kenya	URT	Rwanda
IoT	✓	✓	✓	✓
Big Data	✓	✓	○	✓
3D printing	○	✓	○	○
AI	✓	✓	✓	✓
Robots	○	✓	○	○
Drones	✓	✓	✓	✓
Blockchain	✓	✓	✓	✓

IoT-Internet of Things, AI-Artificial Intelligence

3.4. Strengthening the Potential of Industry 4.0 in EAC

Evidence from the series of industry 4.0 initiatives being launched from time to time shows that most developed countries have started enjoying the benefits of industry 4.0. Moreover, fabulous efforts are being enacted by these developed nations to ensure success in industry 4.0 arena. Yet

industry 4.0 is still a mystery to many developing and least developed countries especially in Africa. A number of them are still stuck in industry 1.0 while others are struggling to transit to industry 2.0. These developing countries have first to enjoy the full benefits of even industry 2.0. Moreover, a number of them still lack access to electricity even for those that have it, it remains highly unreliable [17].

Industry 4.0 disruption is leaving no room for status quo, the developing countries or least developed countries must get ready to leapfrog either willingly or forcefully. Industry 4.0 is a global phenomenon, which requires an international response [245]. Its adaptation and implementation are very expensive processes in both finance and requisite digital skills [246]. Therefore, international collaboration with those countries that are far much advanced in industry 4.0 could be a better option for faster industry 4.0 adaptation in EAC. The benefits of collaboration and partnership can be taken from India as a life example. India has very strong collaboration with key player countries such Germany (Indo-German) [247], Japan (Indo-Japan) [248], United Kingdom (Indo-UK) [122]. Further, South Africa has also demonstrated very strong collaboration with other countries. For instance, "SA-EU strategic partnership" is a collaboration between South Africa and the European Union. The collaboration prospect covers many dimensions ranging from research (Universities), technology transfer, skills development, investment in and mobilization of science, technology and innovation capacities to benchmarking [249].

Although there are number of existing collaboration platforms between the countries within or outside the EAC, new such platforms should be created with a focus on the ongoing digital transformation. It is actually the work of the governments to support the establishment of joint industry 4.0 collaboration platforms, centers of excellence and incubators to alleviate the diffusion of knowledge and technology [250, 251]. While at the University level, joint research programs and exchange programs should be created to surrogate the skilling of labor force in the deployment of industry 4.0 infrastructures [252]. So far so good, as there are numbers of student and staff exchange programs in EAC. For example, the German Academic Exchange Service (DAAD) which is currently strengthening the learning of students majorly in technology and engineering [252]. However, more of these programs should focus particularly on harnessing industry 4.0 technologies from perspectives of their development to applications.

Furthermore, international and regional cooperation play roles in industry 4.0 adaptation and implementation among countries. A number of international cooperation around the globe are striving to ensure success of their member countries in industry 4.0 arena. For instance, the BRICS which is the cooperation between Brazil, Russia, India, China and South Africa have developed a number of working groups and developed initiatives to prepare its members for industry 4.0 disruption [253, 254]. The same efforts are being enacted by other international or regional cooperation such as European Union (EU) and the Cooperation Council for the Arab States of the Gulf (GCC). Therefore, it is necessary for countries to form strong cooperation or join the cooperation either at regional or international levels in order to enjoy the full benefits of industry 4.0 or to activate the technological leapfrogging for the case of least developed countries. EAC is the regional intragovernmental political and economic union [255, 256], just like the GCC. The EAC should develop ingenious strategies that will prepare its members for industry 4.0 disruptions and to awaken least developed members (Burundi and South Sudan). This is because cooperation among countries is an incredible instrument for leapfrogging into industry 4.0 paradise.

Additionally, a lucrative strategy to strengthen the adaptation of industry 4.0 within the private sector and academic entities is through joining open innovation initiatives and technology membership organizations. One of the examples is the "Accenture open innovation initiative". It is a leading global initiative, providing a broad range of services and solutions in strategy, consulting, digital, technology and operations [257]. This initiative is capable of boosting large companies as well as small high-tech firms and startups, hence laying solid grounds for industry 4.0 adaptation [258, 259]. Besides, Industrial internet consortium (IIC) is an internationally recognized open technology membership organization that provide a common understanding to promote interpretation, and deployment of Industrial Internet of Things (IIoT) among companies through published guidelines,

reference frameworks and specifications [260]. IIC was founded in 2014 by five US's giant High-Tech Companies (GE, IBM, Cisco, AT&T and Intel) [261]. Many companies around the world are currently enjoying the benefits from such an astonishing organization. Innovations are essential for successful entry into the era of industry 4.0 and many governments try to promote innovation. However, corporate leaders of companies cannot easily determine innovative initiatives, as they are time consuming, costly, and likely to fail, which is dubbed as a "Leadership gap" in an organization [262, 263]. Therefore, joining or being part of already established innovative initiatives is the option for the companies to benefit and sustain their competitiveness in the current dynamic business environment.

Finally, sound government, corporate, academic and civil society leadership and collaboration (private-public partnership) capabilities to respond to technological, market and other change requirements are remarkably emblematic of industry 4.0 adoption in a country [121]. The ICT policy will have its limits very soon as industry 4.0 disruption is progressing. For this reason, the EAC need to consider industry 4.0 strategy alongside the ICT policy to be successfully competitive. This calls for the governments to rethink about their leadership infrastructure. There is need for structural transformation by developing national policies on industry 4.0, just like ICT policy was formed in the EAC member countries [243]. This is the strategy that has been adopted by many countries including Malaysia [130], Thailand [129] and India [123] to strengthen the adaptation and penetration of industry 4.0.

Conclusion

The present study has successfully explored industry 4.0 initiatives launched by countries worldwide based on electronic data. The estimated percentage of countries with established industry 4.0 initiatives in regions might not depict the real-life percentage, as the study was solely dependent on electronic literature and limited by the availability of published information. Further, only published papers in English were considered. Nevertheless, the study shows the current state of industry 4.0 initiatives launched in countries around the world. Evidences from literature show a number of countries have not yet launched industry 4.0 initiatives. The result of present study highlights that Europe region leads the world as half of its countries have established industry 4.0 strategies already. While Middle East and Africa are still at nascent stages of adoption with only few countries having developed industry 4.0 initiatives.

Industry 4.0 technologies and initiatives are the complementary DNA of industry 4.0. For this reason, implementing industry 4.0 technologies alone is just not enough to succeed in industry 4.0 arena. Every country should ensure that industry 4.0 technologies adaptation advances with launching of initiatives. This is what the industry 4.0 pioneer countries (Germany and US) have pursued and are focusing more on research and development in "science, technology, engineering and innovation" as the promising strategy to harness sustainable competitiveness in the present dynamic business environment. Yet the concept and infrastructure of industry 4.0 have not yet been comprehended by the EAC. This calls for strong collaboration and coordination with industry 4.0 pioneer and expert countries in order to acquire the indispensability such as skills, knowledge, technologies development and methods design.

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