Industry 4.0 Implementation Challenges in an Unfacilitated Environment: A Case of Manufacturing Industries in Zambia

Tola Toyin Afolabi and Levy Siaminwe
Department of Mechanical Engineering
School of Engineering
University of Zambia
Lusaka, Zambia
eng2100200@student.unza.zm, afolabitolatoyin@gmail.com, lsiaminwe@unza.zm

Abstract

The current fourth industrial revolution, called Industry 4.0, implies digitalisation is central to African countries to leverage the African Continental Free Trade Area (AfCFTA) and boost its manufacturing sector. However, the lack of right governmental policies, poor state of industries, and lack of regulatory frameworks in most African countries make digitalization of industries and for the continent to realize the goals of integration in line with AfCFTA complex. For Zambia, where no national Industry 4.0 initiative is in force, how is the manufacturing industry preparing for the digital future? This study was designed to answer this question. The study used a quantitative research design, and a structured questionnaire distributed to manufacturing companies appearing on the Zambia Association of Manufacturers' database for data collection. A total of 50 questionnaires were successfully completed. The data were analysed using SPSS to conduct descriptive statistics and exploratory factor analysis. The results from the study show that the major challenges to the adoption of Industry 4.0 technologies included; high investment cost of Industry 4.0 technologies, need to reduce costs to stay competitive, IT security, growing complexity of processes and lack of skills and insufficient training of the staff. These findings suggest that Zambia is likely to lag the adoption of the current industrial development, digitalization, and greater integration trajectory, and risk being left out of the AfCFTA and Industry 4.0 opportunities. It is recommended that a Industry 4.0 national initiative be put in place to help bolster Industry 4.0 adoption by manufacturing firms in Zambia.

Keywords
Industry 4.0, Industry 4.0 technologies, Manufacturing industry, National initiative and Zambia.

1. Introduction
Industry 4.0, also known as the fourth industrial revolution, refers to the integration of advanced technologies and the Internet of Things (IoT) into various industries, including manufacturing, logistics, and services. This concept is characterized by the use of cyber-physical systems, cloud computing, artificial intelligence, and big data analytics to create smart factories and supply chains that can operate more efficiently and with greater flexibility. Industry 4.0 will make global manufacturing much more connected and competitive in the future. It offers the potential for increased productivity, improved quality, and reduced costs, while also enabling new business models and opportunities for innovation. The fourth industrial revolution presents an opportunity for the manufacturing sector on the African continent to adopt Industry 4.0 technologies, especially as the continent looks to achieve a unified Africa in the Global Supply Chain through the African Continental Free Trade Area (AfCFTA). The AfCFTA was launched to support African countries' industrialisation by promoting linkages across the continent, which would facilitate growth of the manufacturing sector. The current fourth industrial revolution, Industry 4.0, implies digitalisation is central to African countries to leverage the AfCFTA and boost its manufacturing sector. This is critical as history shows that no country has reached an advanced stage of economic and social development without an advanced industrial sector. Industry 4.0 is often implemented with digitalization as the first important step. Digital technologies allow for new business models and value-producing opportunities, and are attainable for most developing countries, such as Zambia. It has been noted that, right from the inception of Industry 4.0, globally many nations stimulated the adoption of Industry 4.0 technologies by launching Industry 4.0 Initiatives that created facilitating environments for accelerated adoption of Industry 4.0 technologies. These Initiatives are important in that; (i) to governments, these represent important

priorities and development goals to help identify changes in policies, incentives, and ideal standard practices, and (ii) to industry, these identify new opportunities brought forth by the real-time access to information, and point to incentives and sources of investment to transform the way they operate. Some notable launched National Industry 4.0 Initiatives around the world include the United States Advanced Manufacturing Partnership program in 2011, France's The New Industrial France, 2013, United Kingdom's Future of Manufacturing in 2013, South Korea's Innovation in manufacturing 3.0 program in 2014, China's Made in China 2025 and Internet Plus program in 2015, Japan's Internet Plus program in 2016, South Africa's National E-strategy-2017, Morocco's Industrial Acceleration Plan in 2017, and Rwanda's Centre for the Internet of things (IoT)-2017. Despite Zambia's declaration to transform into a Nation in which Digital Transformation, Science, Technology and Innovation are the driving force for competitiveness and wealth creation, no national initiative on Industry 4.0 has been launched. It is now accepted that industries of the future are those that embrace the digital world. For Zambia, where no national Industry 4.0 initiative is in force, how is the manufacturing industry preparing for the digital future? This study was designed to answer this question.

The manufacturing sector has been central in the realization of Zambia's economic growth and development, and is a priority sector in the country's industrialisation agenda. Building materials, chemicals, textiles, food and beverage production, and light metal products are among Zambia's main manufacturing industries. Medium-sized businesses and subsidiaries of international corporations make up the majority of the manufacturing sector. Currently, the industry is mostly focused on generating inputs for the local industrial sector, with the majority engaged in agro-processing and the production of consumer goods (KPMG, 2015). The manufacturing sector's value added as a percentage Gross Domestic Product (GDP) grew from about 7.5% in 2010 to 8.1% in 2018 (Zambia Economic Recovery Programme 2020-2023). However, the sector's performance was hampered by the high cost of doing business and an unstable macroeconomic environment, and in 2019, these challenges were exacerbated by the COVID-19 pandemic, resulting in the sector shrinking by 4.6% in the second quarter of 2020. The Government responded to challenges posed on the country's industrialisation agenda by the COVID-19 pandemic and other structural constraints by making adjustments to the tax policy framework to support the expansion of the manufacturing base (Zambia Economic Recovery Programme 2020-2023). Under this measure, Zambia aims to aggressively pursue export market opportunities through investment promotion missions in markets such as the AfCFTA and the Tripartite Free Trade Agreement (COMESA-EAC-SADC). This is in line with the "Vision 2030", developed in 2006 to guide Zambia's economic development by the year 2030, wherein manufacturing is envisioned to be "technology based and export focused manufacturing sector, which is dynamic and competitive with effective entities that add value to the locally abundant natural resources by 2030." (Republic of Zambia Vision 2030, 2006). These aspirations should generally lead the majority of manufacturing companies in Zambia move to Industry 4.0 to stay competitive. A national initiative becomes critical in this case because it would create the general preconditions for digitization and for innovation, which are important for the development of Industry 4.0. Unfortunately, no such initiative is currently in existence in Zambia.

1.1 Objectives

This study evaluates the awareness and challenges of implementing Industry 4.0 in manufacturing firms in Zambia in the absence of a National Industry 4.0 Initiative.

2. Literature Review

The fourth Industrial Revolution and the phrase "Industrie 4.0" all relate to the current industrial configuration strategy (Da Silva et al. 2020). The origin of the fourth Industrial revolution came about after the Hannover Fair in 2011. The German government formally announced it in 2013 as a German-planned scheme to play a revolutionary part in its industrial Sector (Lu 2017; Roblek et al. 2016; Vaidya et al. 2018; Xu et al. 2018). An intelligent network of devices and industrial processes known as "Industry 4.0" is controlled by information and communication technologies for physical and digital connectivity (Müller et al. 2018). The fourth industrial revolution has given society new opportunities and prospects. It is constructed on the back of many of the previous industrial revolution's accomplishments (Kayembe. 2019).

According to Kiel et al. (2017), technological expertise and knowledge are prioritized in Industry 4.0 while the economic conversation is still in its infancy. One of the main obstacles to Industry 4.0 projects for achieving sustainability in the supply chain could be the absence of a clearly defined return on investment. Therefore, government directives and policies are essential for implementing Industry 4.0 and creating sustainable supply chains. In its report, Mckinsey Digital (2016) emphasizes that the government's capacity to adopt the appropriate policies is essential for successful adjustment to the new technology environment. Governments unable to implement effective long-term strategies will put their economies in danger. In other words, when all other economies are proliferating, those unable to adjust to the new situation will see their competitiveness decline, their revenue fall, and their spending rise, increasing the likelihood of bankruptcy (Zervoudi 2020). Currently, most economies, including Zambia, lack clear government policies and directives on industry 4.0. There is no facilitating environment in such cases.

The likely reason for the non-existence of Industry 4.0 initiatives in most cases is that governments are uncertain about the likely effects of Industry 4.0. As a result, government agencies and policy experts have not provided a path for replacing conventional business procedures with more intelligent and sustainable ones (Luthra and Mangla 2018). Business organizations view financial limitations as a significant barrier to their ability to progress their skills in cutting-edge machinery, facilities, and environmentally friendly process innovations in Industry 4.0 (Alfred et al. 2017; Nicoletti,2017). Additionally, manufacturing firms need to understand the economic benefits of digitization for influential Industry 4.0 adoption, and most companies do not know the business benefits that may originate from implementing Industry 4.0 (Hofmann and Rüsch 2017). Further, Industry 4.0 demands additional personnel abilities and skills, including ICT knowledge, transdisciplinary competencies, and unique personality qualities. Given its digital foundation, ICT knowledge and proficiency are essential (Jayashree et al. 2021).The major challenges to the implementation of industry 4.0 reported in literature are shown in Table 1 below.

Table 1. Major challenges to the implementation of Industry 4.0

Code	**Challenges to use Industry 4.0 technologies**	**Supporting articles**
C1	Exposure to global competition	(Hecklau et al., 2016)
C2	Cost of retaining qualified I.T. staff	(Zadjali and Ullah, 2021)
C3	Need to reduce costs to stay competitive	(Hecklau et al., 2016)
C4	High investment cost of 4IR technologies	(Schumacher et al., 2016; Vrchota and Volek, 2019)
C5	Demographic change and changing social values	(Hecklau et al., 2016)
C6	Increasing Virtual work	(Jochen, 2022)
C7	The glowing complexity of processes	(Hecklau et al., 2016; Luthra and Mangla, 2018)
C8	The exponential growth of technology and data usage	(Hecklau et al., 2016)
C9	Growing collaborative work platforms	(Lichtblau et al., 2015; Luthra and Mangla, 2018; Pfohl et al., 2013)
C10	Extensive I.T. infrastructures to be built and implemented	(Jayashree et al., 2020; Pfohl et al., 2013)
C11	Need to develop standardized interfaces and open architecture	(Duarte and Cruz-Machado, 2017; Hecklau et al., 2016)
C12	I.T. security	(Pereira et al., 2017; Wang et al., 2016)
C13	Climate change and resource scarcity	(Hecklau et al., 2016; Zervoudi, 2020)
C14	Little knowledge about the concept of Industry 4.0	(Müller et al., 2017)
C15	Consequences of risks of automation	(Holzer, 2022)
C16	Lack of technology strategies	(Raj et al., 2020; Schröder, 2016)
C17	Lack of Top Management Support	(Luthra and Mangla, 2018; Raj et al., 2020; Sony and Naik, 2020)
C18	Lack of skills and insufficient employee training	(Luthra & Mangla, 2018)
C19	Standardization	(Germany Trade and Invest, 2014; Kusiak, 2018; Yi et al., 2013)
C20	Data security and personal privacy	(Schröder, 2016)
C21	Intellectual Property rights	(Zadjali and Ullah, 2021)

3. Methodology

The study methodology used a quantitative research design, and a structured questionnaire distributed to manufacturing companies appearing on the Zambia Association of Manufacturers' database for data collection. A cross-sectional survey was used to collect data on the Demographic Profile, Awareness of Industry 4.0, and Challenges of Implementing 4IR Technologies. A Likert Scale with five levels (1-Non, 2- Low, 3-Moderate, 4-High, 5-Very high) was used to assess the respondents' Knowledge Level of main Technologies/Concepts of Industry 4.0 as a measure of awareness. The Respondents were required to indicate their respective positions on a five level Likert Scale (1-Strongly disagree, 2-Disagree, 3- Neutral, 4-Agree, 5-Strongly agree) to identified Challenges of Implementing 4IR Technologies from literature review, which were ranked and conducted an Exploratory Factor Analysis (EFA) to group the challenges. The Statistical Package for Social Sciences (SPSS) Version 25 was the tool used for both descriptive statistic and EFA.

4. Data Collection

The survey was conducted online using the google form, as well as administered physically to mitigate the low response rate on the online survey. The target respondents were directors, CEOs, and executives, specifically CEOs who ought to have the best knowledge about policy development in their respective firms, and are likely to impact the technology implementation process. The google form link was sent in July 2022, and a reminder was sent after three weeks. The physical data collection was conducted between September and October 2022. The collected data was analysed through frequency analysis. The Statistical Package for Social Sciences (SPSS) Version 25 was used to create tables, graphs and charts as well as conduct reliability and factor analysis. From the 79 questionnaires that were administered, 55 questionnaires were completed both online and hard copies, which represents a response rate of 70%. This is considered an adequate response rate according to Sekaran and Bougie, (2016) who recommend 30% and above as acceptable for surveys. After data cleaning was conducted, five of the returned questionnaires were removed due to missing data, resulting in a final sample of 50 manufacturing companies, comprising Manufacturing of metal products (13), Food and beverages (11), Agro processing (9), Chemicals, rubber and plastic industries (8), Oil and gas (3), Mineral processing (2), Textile and leather industries (2), Manufacturing of equipment (1), and Wood industries (1).

5. Results and Discussion

5.1 Numerical Results

The level of knowledge of the main technologies in Industry 4.0 by the respondents as measured using a five scale Likert scale is shown in Table 2, presenting the mean and standard deviation on Industry 4.0 technologies based on the overall response of the manufacturing companies. The first ten Industry 4.0 technologies that the companies are aware of includes internet of things, mobile technologies, cybersecurity, big data and analytics, smart sensors, cloud computing, predictive maintenance, human-computer interaction, supervisory control and data acquisition, and real time location system. These are generally most popular technologies that have a progressive evolution from the Third Industrial Revolution (3IR), characterised by technological developments in production, energy, and distribution as the driving forces behind the third industrial revolution. Internet technology, Renewable energy, and Information and commutations technology stand out, with the introduction of nuclear power and the widespread usage of electronics being two of the most significant developments of the 3IR period. The least knowledge levels were observed on the more recent developments, which included cyber-physical system, autonomous robots, block chain, and quantum computing.

Table 2. Respondents' Knowledge of main Technologies of Industry 4.0

Industry 4.0 Technologies	**Mean**	**SD**	**Industry 4.0 Technologies**	**Mean**	**SD**
Internet of Things	3.14	1.40	Manufacturing execution system	2.06	1.24
Mobile Technologies	2.94	1.39	Simulation Models	2.02	1.33
Cybersecurity	2.76	1.39	Advanced Human to Machine Interface	1.98	1.27
Big Data and Analytics	2.58	1.25	Virtual Reality	1.96	1.24
Smart Sensors	2.58	1.37	Additive Manufacturing	1.94	1.19
Cloud Computing	2.50	1.36	Simulation	1.94	1.24
Predictive Maintenance	2.50	1.34	Embedded Systems	1.82	1.16
Human Computer Interaction	2.44	1.36	Artificial Intelligence	1.82	1.10
Supervisory control and data acquisition	2.40	1.44	Augmented Reality	1.74	1.10

Real Time location System	2.38	1.29	Drones, UAV, UASs, and RPA	1.70	1.15
Product Lifecycle management	2.30	1.28	Cyber-Physical System	1.66	1.04
Horizontal and Vertical System Integration	2.26	1.24	Autonomous Robots	1.54	0.89
Plant Simulation	2.14	1.40	Block chain (Bitcoin, Cryptocurrency, digital currency)	1.52	1.05
Radio Frequency Identification	2.14	1.34	Quantum Computing	1.42	0.86

Generally, from the results in Table 2, it is clear that there is a low to moderate knowledge on the Industry 4.0 technologies among manufacturing industries in Zambia. This can be attributed to low awareness of Industry 4.0 in Zambia as there is no national initiative to promote adoption of Industry 4.0 technologies.

Table 3 shows the mean and standard deviation on the challenges of implementing Industry 4.0 based on the overall response of the manufacturing companies. It can be seen that the mean values were within 3.02 to 3.98 which is acceptable on a five point Likert scale, that is, all the challenges are significant. According to Harada *et al.*, (2015), any variable with a score of more than three-fifths (3/5) on the Likert scale, or a mean value of 3 on a scale of one to five can be considered significant. The identified challenges have standard deviations (SDs) that are approximately 1.00. This suggests that there is little variation in the dataset for this study based on the opinions of the respondents (Ojo et al., 2021). Therefore, the 21 challenges could be described as substantial challenges to the implementation of Industry 4.0 in Zambia's manufacturing sectors.

Table 3. Respondents' Challenges of Implementing Industry 4.0

Challenges of Implementation	**Mean**	**SD**	**Challenges of Implementation**	**Mean**	**SD**
High investment costs of 4IR technologies	3.98	1.10	Climate change and resource scarcity	3.46	1.15
Need to reduce costs to stay competitive	3.86	1.09	Data security and personal privacy	3.44	1.07
IT Security	3.74	1.08	Lack of skills and insufficient training of the staff	3.42	1.16
Growing complexity of processes	3.68	0.98	Demographic change and changing social values	3.40	1.03
Little knowledge about the concept Industry 4.0	3.60	1.16	Growing collaborative work on platforms	3.38	1.09
Extensive IT infrastructures to be built and implemented	3.58	0.97	Increasing virtual work	3.38	1.12
Need to develop standardized interfaces and open architecture	3.58	1.07	Standardization	3.36	0.96
Cost of retaining qualified IT staff	3.58	1.16	Exposure to global competition	3.34	1.06
Exponential growth of technology and data usage	3.56	1.11	Lack of technology strategies	3.28	1.16
Intellectual property rights	3.50	1.05	Consequences and risks of automation	3.16	1.09
			Lack of Top management support	3.02	1.22

An exploratory factor analysis was done on the challenges. Table 4 shows the KMO results for the challenges to the implementation of Industry 4.0 in manufacturing firms in Zambia. The first analysis done showed a value of 0.798 and a chi-square of 691.368 and degree of freedom of 210 at a significant of 0.000. The first five factors showed a % variance of 72.1 while the remaining 27.9% contributed to the 16 factors. The grouping of the dataset was examined for reliability using Cronbach alpha (α) and the values obtained was 0.874, 0.878, 0.867, 0.691, and 0.732 respectively .The challenges "standardization" and "need to develop standardized interfaces and open architecture" had values of 0.483 and 0.443 which is below 0.5 and therefore was deleted and another factor analysis was conducted. This second analysis showed a result for KMO to be 0.773 which is acceptable. It shows that 77.3% of the data collected was satisfactory, with a p value < 0.05 and a degree of freedom of 171, the approximate chi square is 595.448 showing that most of the challenges are correlated at a level of 5%.

Table 4. KMO and Bartlett's test of sphericity for challenges to implement

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.773
Bartlett's Test of Sphericity	Approx. Chi-Square	592.448
	Df	171
	Sig.	0.000

Table 5 shows the results with five (5) components from the factor analysis that were grouped based on the researcher's judgment. The five factors are therefore named;

(i) Socio-technical challenges: this included 7 challenges that accounted for 44.37% of the total variance.
(ii) Organizational challenges: this consisted of 4 challenges that account for 10.22% of the total variance.
(iii) Legal challenges: this consisted of 3 challenges that accounts for 6.41% of the total variance
(iv) Environmental challenges; this comprised of 3 challenges that accounts for 5.80% of the total variance;
(v) Economic challenges: this included 2 challenges that accounts for 5.30% of the total variances.

Table 5. Factor analysis for challenges

Challenges to Implementation	Component					
	1	2	3	4	5	Alpha
Growing collaborative work on platforms	0.815					0.874
Exponential growth of technology and data usage	0.745					
Increasing virtual work	0.682					
Demographic change and changing social values	0.673					
Little knowledge about the concept Industry 4.0	0.645					
Growing complexity of processes	0.628					
Consequences and risks of automation	0.576					
Lack of technology strategies		0.862				0.878
Cost of retaining qualified IT staff		0.768				
Lack of skills and insufficient training of the staff		0.719				
Lack of Top management support		0.691				
Intellectual property rights			0.877			0.844
Data security and personal privacy			0.670			
IT Security			0.595			
Climate change and resource scarcity				0.832		0.732
Exposure to global competition				0.689		
Extensive IT infrastructures to be built and implemented				0.531		
High investment costs of 4IR technologies					0.834	0.691
Need to reduce costs to stay competitive					0.618	

(i) **Social-technical challenges**: The challenges under this component are *Growing collaborative work on platforms* with a significance of 0.815, Digitization of the supply chain is necessary for the implementation of industry 4.0 to be successful. Collaborating with other elements or members in a supply chain with a large amount of data (Lichtblau et al., 2015). *Exponential growth of technology and data usage* (Sig. = 0.745), *Increasing virtual work* (Sig. = 0.682), *Demographic change and changing social values* (Sig. =0.673). Another significant concern is the increasing average age of the workforce as a result of demographic shift. At shop floor workplaces, the elderly are frequently perceived as a less powerful group. However, because the senior population will soon be the largest available workforce, it is critical to recognize, exploit, and properly integrate their potential (Wolf et al., 2018; World Economic Forum, 2017). *Little knowledge about the concept Industry 4.0* (Sig. = 0.645), *Growing complexity of processes* (Sig. =0.628), and *Consequences and risks of automation* (Sig. = 0.576).

(ii) **Organisational Challenges**: The challenges under component two are *lack of technology strategies* (Sig. = 0.862), Raj et al. (2020) contend that adopting Industry 4.0 is a strategic choice and that hesitations at the highest management level may make it challenging to create a digital strategy. The *cost of retaining qualified staff* (Sig. = 0.768), as Wolf et al., (2018) pointed out, employment could have a substantial impact on the implementation of Industry 4.0. The number of job positions should be reduced in the first phase. Over time, employment openings may expand, and a great emphasis may be placed on highly trained individuals, providing firms with a competitive advantage (Mura et al., 2017). History clearly demonstrates that increased labour productivity has contributed to the liberation of employees from their tasks. Industry 4.0 will result in the abolition of low-skilled occupations in the industry (assembly line production) and other activities (Vrchota and Volek, 2019). *Lack of skills and insufficient training of the staff* (Sig. 0.719), even after Industry 4.0 has been implemented, improving the organization's productivity may not be possible without the necessary training (Luthra and Mangla, 2018) and *lack of top management support* (Sig. = 0.691); top management must be involved with and supportive of Industry 4.0 (Sony and Naik, 2020). In the context of Industry 4.0, top management impacts the company's financial and strategic direction (Sony and Naik, 2020).

(iii) **Legal challenges**: The challenges are: *Intellectual property rights* (Sig. =0.877), *Data security and personal privacy* (Sig. = 0.670), and *I.T. Security* (Sig. = 0.595). Cyber-physical systems and their digital integration across corporate functions are a distinguishing aspect of e-business security concerns. Firms that perform internet-based e-business have less control over data than those who use traditional systems. Furthermore, integration along the value chain entails the dissemination of core company data, and even if access is controlled, the number of physical entry points for fraud usage grows. These safety problems are amplified in the setting of self-regulating industries (Prause, 2019).

(iv) **Environment Challenges**: This included *climate change and resource scarcity* with a sig. of 0.832, *exposure to global competition* (Sig. = 0.670). *Extensive IT infrastructures to be built and implemented* (Sig =0.531). Higher infrastructure and efficient internet networks are required to successfully handle the networked devices. Internet access in Zambia, particularly in rural areas, has to be increased (Luthra and Mangla, 2018).

(v) **Economic challenges**: The challenges here are *High investment costs of 4IR technologies* (Sig. = 0.834) and *Need to reduce costs to stay competitive* (Sig. = 0.618). According to Erol et al., (2016), challenges occur for small and medium-sized firms in particular because of the enormous financial resources needed to acquire new technology for Industry 4.0. Regarding capital requirements, the majority of benefits can be obtained from less expensive solutions, such as the increasingly available RFID and NFC sensor systems for smart logistics, even though the infrastructure required for the efficient operation of several integrated systems (for example, in the horizontal digital integration through value networks) may, in fact, require significant investments.

5.2 Graphical Results

Figure 1 shows the ICT tools used by different manufacturing companies surveyed. The ICT tools used the most is Microsoft tools with a percentage of 96, the second most used tool is automated equipment having a percentage of 72, thirdly project management tools were used with a percentage of 48, and the least used are CyberCAD (10%), CyberCut (6%), and robots (4%). Most of these ICT tools are widely used because they were introduced in previous industrial revolutions like the third industrial revolution where Information Communication Technology gained widespread use. Figure 2 shows the ICT tools usage by type of manufacturing sector. It can be seen from Figure 2 that all companies from the manufacturers of metal products, agro-processing sector, textile and leather, mineral processing, and manufacturers of equipment used Microsoft tools. Also, 20% out of 22% of the food and beverages made use of Microsoft tools and 14% out of 16% of the chemical industries made use of it. The automated equipment's were used by 18% out of the 26% manufacturers of metal products, 18% out of 22% food and beverage industry and 14% out of 16% in the chemicals, rubber and plastic industries.

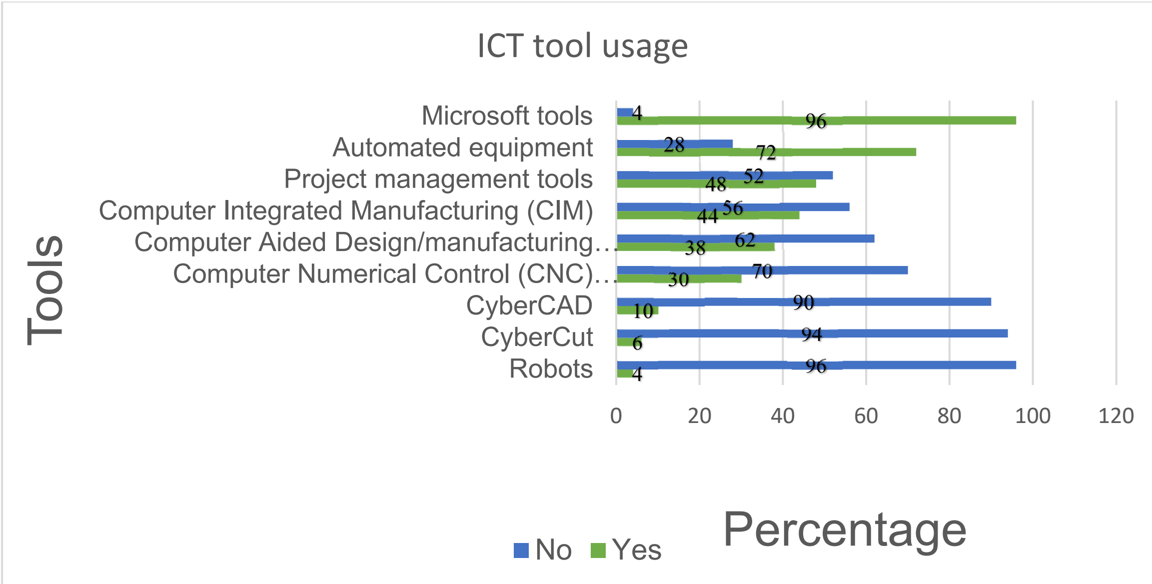

Figure 1. ICT tool usage by the different manufacturing sector

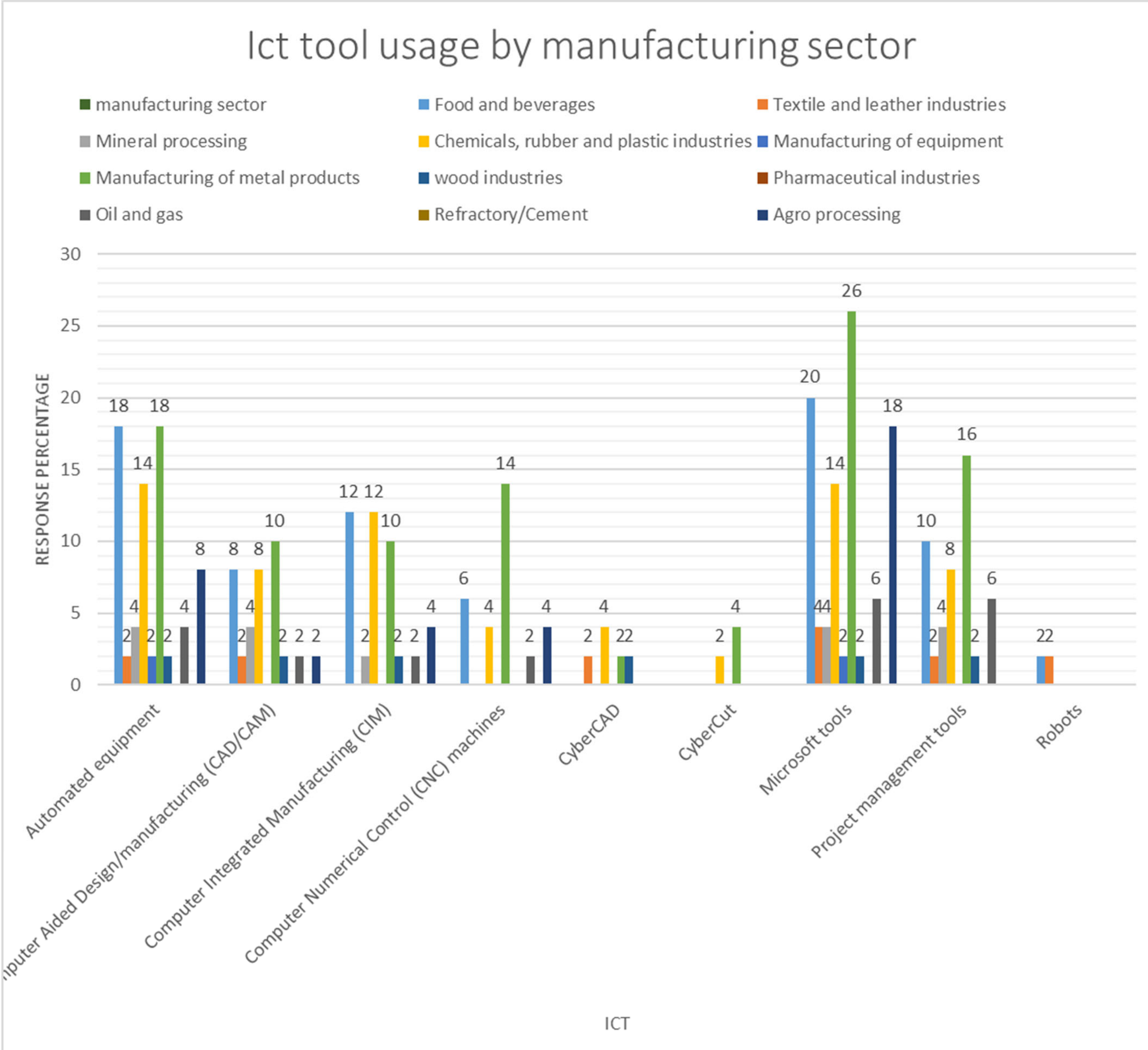

Figure 2. ICT Tools Usage by Manufacturing Sub-sectors

An expected result of digitalization is an increase in the use of ICT technologies. However, digitalization is not only about gathering as much technology as possible; the resulting data sets should be processed to support decision-making (where possible, in real-time by machines). However, over the past few years, the growing availability of cloud storage, rental processing power, and all-pervasive network connectivity has made it possible to analyse data in ways that were previously not imaginable (Gilchrist 2016; Mogos et al. 2019). As can be seen from Figure 2, Microsoft tools and automated equipment are the top most used ICT tools by all of the manufacturing sub-sectors represented, which is similar with the results of Mogos et al. (2019). The tools utilising current computing power, connectivity, and new forms of human-machine interaction that drive the Industry 4.0 phase of manufacturing sector digitisation, these were hardly in use.

The ranking of the challenges presented in Table 3 was based on the combined percentage score on Strongly Agree and Agree level on the five scale Likert Scale used, The Figure 3 below shows this ranking of the major challenges to the implementation of Industry 4.0, it can be seen that 76% of the respondents stated that 'Need to reduce costs to stay competitive' and 72% stated that 'High investment costs of 4IR technologies' are two of the most important challenges. 'Growing complexity of processes', 'Cost of retaining qualified IT staff', were stated as the third most important challenges with a percentage of 64%. The challenges with the least percentages of 40% and 32% are 'Consequences and risks of automation' and 'Lack of top management support'. This is encouraging because it shows that Top management would support Industry 4.0 programmes if the perceived costs of 4IR technologies could be addressed. Economic challenges do stand out as number one challenge that needs addressing.

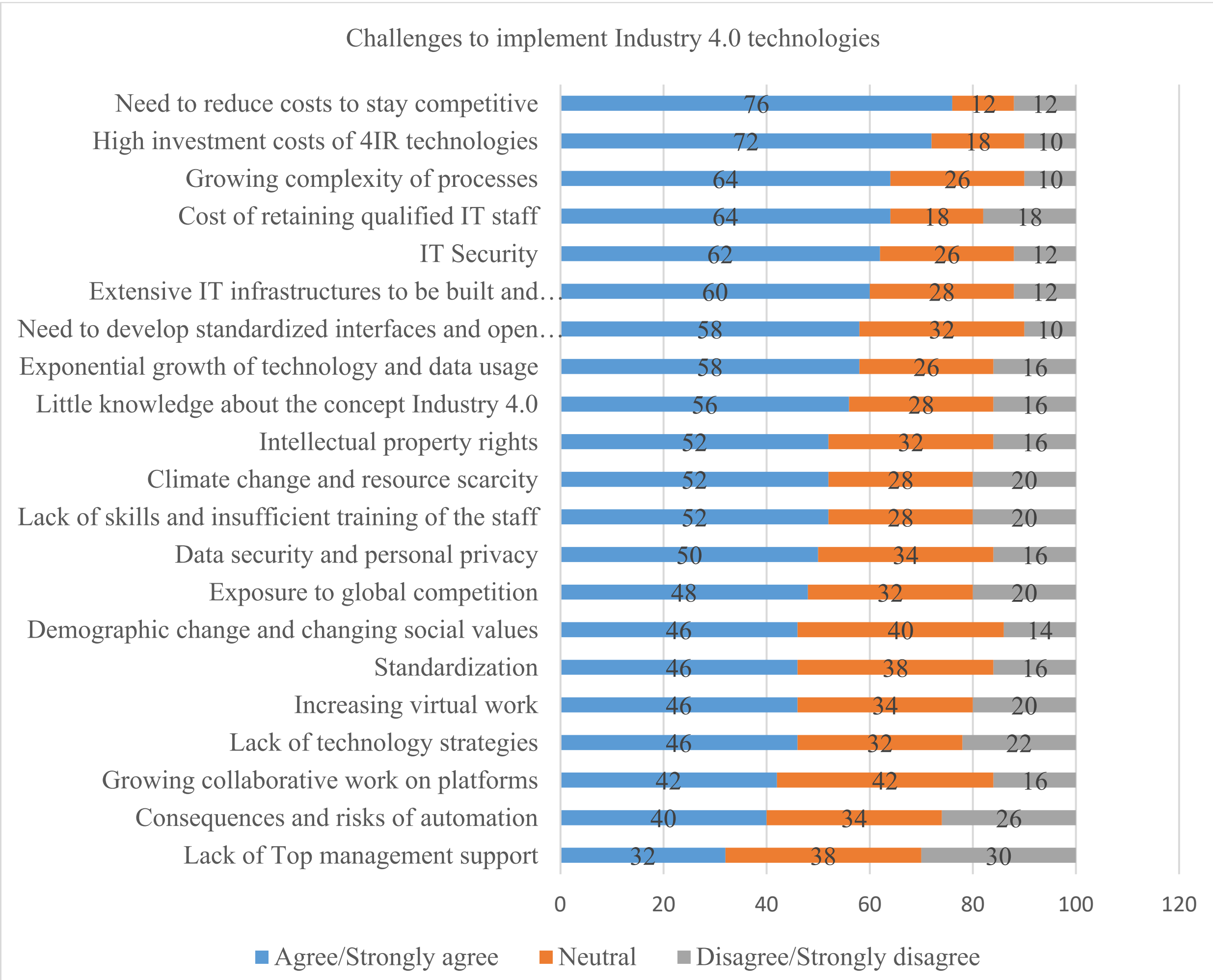

Figure 3. The major challenges to the implementation of Industry 4.0

The respondents' indication that the requirement for high investments is a significant challenge, comes as no surprise as previewed literature already identified the lack of resources, insufficient top management incentives, and a lack of the necessary skills as common obstacles to digital transformation (Gilchrist 2016; Mogos et al. 2019). According to Erol et al. (2016), challenges occur for small and medium-sized firms in particular because of the enormous financial resources needed to acquire new technology for Industry 4.0. Regarding capital requirements, the majority of benefits can be obtained from less expensive solutions, such as the increasingly available RFID and NFC sensor systems for smart logistics, even though the infrastructure required for the efficient operation of several integrated systems (for example, in the horizontal digital integration through value networks) may in fact require significant investments. Contrary to Gilchrist (2016) and Mogos et al. (2019) identifying 'insufficient top management incentives' as a one of the common obstacles to digital transformation, this study found 'Lack of Top management support' to be ranked as the least challenge. This could be due the fact that in an unfacilitated environment, organisation are left to map out their respective strategies in order to survive in the global marketplace. These result is supported by Bogoviz et al., (2019) study, which states that developed countries have developed national strategies and policies to promote Industry 4.0 technologies, whereas developing countries have adopted Industry 4.0 technologies on a corporate level, relying on individual corporate initiatives than national and coordinated policies. Because of various policies for the advancement of Industry 4.0, the influencing challenges in industrialized and developing countries differ.

6. Conclusion

The knowledge level analysis produced the mean Likert Scores for the majority Industry 4.0 technologies between 2 and 3 scales, representing Low and Moderate levels, respectively. This implies that Manufacturing Industries in Zambia had a low to moderate knowledge on Industry 4.0, meaning most of the companies had a low awareness on the main technologies of Industry 4.0. They had low to moderate knowledge on internet of things, mobile technologies, cybersecurity, smart sensors, big data and analytics, cloud computing and predictive maintenance, all of which are core to digitisation. Some of the main challenges to implement Industries 4.0 identified by the companies were 'high investment costs and a need to reduce costs in order to remain competitive as common challenges to digital transformation. On the question of whether the company had any strategy to move to Industry 4.0, 29% of respondents indicated that they do not have a strategy in place for industry 4.0, while 18% are preparing one, and 12% said they have a strategy for Industry 4.0 but it's not part of their company strategy. Only 22% said they have a strategy and its part of their company strategy. Clearly initiatives at enterprise level are not leading to expected 4IR technologies adoption levels. These findings suggest that Zambia is likely to lag the adoption of the current industrial development, digitalization, and greater integration trajectory, and risk being left out of the AfCFTA and Industry 4.0 opportunities. The establishment of a national Industry 4.0 initiative would create an environment that facilitates industry adoption of new technologies because the economic challenges identified can easily be addressed by the Government.

References

Alfred, T., Kristofer, B., Julien, P., Michael, L., Charlotta, J., Thomas, L., and Bengt, An event-driven manufacturing information system architecture for industry 4.0. *International Journal of Production Research*, vol. 55 no. 5, pp. 1–17, 2017.

Bogoviz, A. V., Osipov, V. S., Chistyakova, M. K., and Borisov, M. Y.,Comparative analysis of formation of industry 4.0 in developed and developing countries. *Studies in Systems, Decision and Control*, vol. 169, pp.155–164, 2019.

Da Silva, V. L., Kovaleski, J. L., Pagani, R. N., Silva, J. D. M., and Corsi, A., Implementation of Industry 4.0 concept in companies: empirical evidences. *International Journal of Computer Integrated Manufacturing*, vol. 33, no. 4, pp. 325–342, 2020.

Duarte, S., and Cruz-Machado, V., An investigation of lean and green supply chain in the Industry 4.0. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, pp. 255–265, July, 2017.

Erol, S., Schumacher, A., and Sihn, W., Strategic guidance towards industry 4.0 – A three-stage process model. *Internantional Conference on Competitive Manufacturing*, pp. 495–501, *January*, 2016.

Gilchrist, A., Introducing Industry 4.0. *Springer*, pp. 195–215, 2016.

Germany Trade and Invest., Industrie 4.0 Germany Market Report and Outlook, 2014.

Harada, T., Abe, T., Kato, F., Matsumoto, R., Fujita, H., Murai, S., Miyajima, N., Tsuchiya, K., Maruyama, S., Kudo, K., and Shinohara, N., Five-point Likert scaling on MRI predicts clinically significant prostate carcinoma Urology imaging. *BMC Urology*, vol. 15, no.1, pp. 1–8, 2015.

Hecklau, F., Galeitzke, M., Flachs, S., and Kohl, H., Holistic Approach for Human Resource Management in Industry 4.0. *Procedia CIRP*,vol. 54, pp. 1–6, 2016.

Hofmann, E., and Rüsch, M., Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, vol. 89, pp. 23–34, 2017.

Holzer, H. J. , *Understanding the impact of automation on workers, jobs, and wages*, Available: https://www.brookings.edu/blog/up-front/2022/01/19/understanding-the-impact-of-automation-on-workers-jobs-and-wages/ Accessed on December 21, 2022.

Jayashree, S., Reza, M. N. H., and Malarvizhi, C. A, Understanding the challenges and opportunities of industry 4.0- a budge towards sustainability. *International Journal of Advanced Science and Technology*, vol. 29, no. 6, pp. 366–376, 2020.

Jayashree, S., Reza, M. N. H., Malarvizhi, C. A. N., and Mohiuddin, M., Industry 4.0 implementation and Triple Bottom Line sustainability: An empirical study on small and medium manufacturing firms. *Heliyon*, vol. 7, no.

8, 2021.
Jochen, A., *More Than Machines: How Industry 4.0 Can Augment Your Human Workforce*. Available: https://www.forbes.com/sites/nokia-industry-40/2022/09/27/more-than-machines-how-industry-40-can-augment-your-human-workforce/?sh=27fe2eed1e5a. Accessed on December 21, 2022
Kayembe, C., and Nel, D. Challenges and Opportunities for Education in the Fourth Industrial Revolution, *African Journal of Public Affairs*, vol. 11 no. 3, pp. 79–93, 2019.
Kiel, D., Müller, J. M., Arnold, C., and Voigt, K. I., Sustainable industrial value creation: Benefits and challenges of industry 4.0. In *International Journal of Innovation Management* , vol. 21, no. 8, 2017.
Kusiak, A., Smart manufacturing. *International Journal of Production Research*, vol. 56, no.1–2, pp. 508–517, 2018.
Lichtblau, K., Volker, S., Roman, B., Manuel, B., Martin, B., Millack A, and M, S., Industrie 4.0-Readiness-Check. Available: https://www.industrie40-readiness.de/?lang=en Accessed on October 19, 2022.
KPMG, Manufacturing in Africa: Sector Report, 2015.
Lu, Y., Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, vol. 6, pp. 1–10, 2017.
Luthra, S., and Mangla, S. K. Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, vol. 117, pp.168–179, 2018.
Mckinsey Digital., *Industry 4.0 after the initial hype: Where manufacturers are finding value and how they can best capture it*, 2016.
Mogos, M. F., Eleftheriadis, R. J., and Myklebust, O., Enablers and inhibitors of industry 4.0: Results from a survey of industrial companies in Norway. *Procedia CIRP*, vol. 81, pp. 624–629, 2013.
Müller, J., Dotzauer, V., and Voigt, K. I., Supply Management Research. *Supply Management Research*, pp. 165–179 2017.
Müller, J. M., Kiel, D., and Voigt, K. I., What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability (Switzerland)*, vol. 10*,* no. 247, pp.1–24, 2018.
Mura, L., Ključnikov, A., Tvaronavičienė, M., and Androniceanu, A. Development trends in human resource management in small and medium enterprises in the Visegrad Group. *Acta Polytechnica Hungarica*, vol. 14, no.7, pp.105–122, 2017.
Nicoletti, B., Agile procurement. In *Agile Procurement,* vol. 2, 2017.
Pereira, T., Barreto, L., and Amaral, A.,Network and information security challenges within Industry 4.0 paradigm. *Procedia Manufacturing*, vol. 13, pp. 1253–1260, 2017.
Pfohl, H., Yahsi, B., and Kurnaz, T., Concept and Diffusion-Factors of Industry 4.0 in the Supply Chain Hans-Christian. *Dynamics in Logistics*, Springer International Publishing, pp. 381–390, 2013.
Prause, M., Challenges of Industry 4.0 technology adoption for SMEs: The case of Japan. *Sustainability (Switzerland)*, vol. 11, no. 20, 2019.
Raj, A., Dwivedi, G., Sharma, A., Lopes de Sousa Jabbour, A. B., and Rajak, S., Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics*, vol. 224, 2020.
Republic of Zambia Vision 2030, A Prosperous Middle-Income Nation by 2030, 2006.
Roblek, V., Meško, M., and Krapež, A., A Complex View of Industry 4.0. *SAGE Open*, vol. 6*,* no. 2, pp. 1–11, 2016.
Schroeder, A., Bigdeli, A. Z., Zarco, C. G., and Tim, B., Capturing the benefits of industry 4.0: a business network perspective. *Production Planning and Control*, vol. 30*,*no. 16, pp. 1305–1321, 2019.
Schumacher, A., Erol, S., and Sihn, W., A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*, vol. 52, pp.161–166, 2016.
Sekaran, U., and Bougie, R., *Research Methods for Business: A skill-building approach,* 7th edition, John Wiley and Sons Ltd., 2016.
Sony, M. ;, and Naik, S., Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An Internation Journal*, vol. 27, no. 7, pp. 2213–2232. 2019.
Vaidya, S., Ambad, P., and Bhosle, S., Industry 4.0 - A Glimpse. *Procedia Manufacturing*, vol. 20, pp. 233–238, 2018.
Vrchota, J., and Volek, T. Factors Introducing Industry 4 . 0 to SMES, *Social sciences,* vol. 8, no. 130, pp. 1-10, 2019.
Wang, S., Wan, J., Li, D., and Zhang, C., Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks*, 2016.
Wolf, M., Kleindienst, M., Ramsauer, C., Zierler, C., and Winter, E., Current and Future Industrial Challenges: Demographic Change and Measures for Elderly Workers in Industry 4.0. *ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering Tome XVI Fascicule*, vol. *1,*no.1, pp. 67–77, 2018.
World Economic Forum.,The Future of jobs, Employment, Skills and Workforce Strategy for the Fourth Industrial

Revolution. In *Global Challenge Insight Report* (Issue January), 2017.
Xu, L. Da, Xu, E. L., and Li, L., Industry 4.0: State of the art and future trends. *International Journal of Production Research*, vol. 56, no. 8, pp. 2941–2962, 2018.
Yi, L., Xiaojun, D., Chengli, Z., and Lida, X., Systems Science: Methodological approaches. In *Systems science; Methodological approaches*. Taylor & Francis, 2013.
Zambia Chamber of Commerce and Industry, *Economic Recovery Programme Analysis,* 2020.
Zadjali, S. Al, and Ullah, A., Impact of Industry 4.0 in Manufacturing Sector. *The International Journal of Management Science and Business Administration*, vol. 7, no.6, pp. 25–33, 2021.
Zervoudi, E. K.. Fourth Industrial Revolution: Opportunities, Challenges, and Proposed Policies. *Industrial Robotics - New Paradigms*, pp. 1–25, 2020.

Biographies

Tola Toyin Afolabi is a Master's student of Production Engineering and Management at the University of Zambia, Lusaka, Zambia. She is a recipient of the Strengthening mobility and Promoting Regional Integration of Engineering Education in Africa (SPREE) scholarship award funded by the Intra-Africa Academic Mobility Scheme of the European Union and African Union. Tola has a Bachelor of Engineering in Metallurgical and Materials Engineering from the Federal University of Technology, Akure, Nigeria. After graduation, she had her internship at an international Engineering company, KETSWA Engineering and Project Management Limited, Nigeria office. Her research interests include Additive Manufacturing, Quality Management, Industry 4.0 and Materials Characterization. She is a Graduate Member of the Nigerian Society of Engineers (NSE) and the Nigerian Metallurgical Society (NMS). She has attended different workshops and conferences and written a few conference papers.

Professor Levy Siaminwe is an Associate Professor of Production Engineering (Manufacturing Technology and Management Science) at the University of Zambia. He holds a Bachelor of Engineering with distinction in Mechanical Engineering from the University of Zambia, Master of Science Degree in Computer Integrated Manufacture (CIM) and a Doctorate Degree from Loughborough University, Loughborough, England. He is a Fellow of the Engineering Institution of Zambia (EIZ), and a registered Engineer with the Engineering Registration Board of Zambia (EngRB); His research interests include Manufacturing Systems Management, Quality Management, Metal Casting, Production Engineering, and Project Management. Professor Levy is the Chief Editor of the Journal of Natural and Applied Sciences, a journal of the University of Zambia. He has lectured for over 20 years and taught courses in Production Management, Quality Management and Project Management. He has also Supervised 2 Ph.D. students and 24 Masters Students as a sole supervisor and co-supervisor in different countries like Zambia, Sweden and the Netherlands. Professor Levy was the Project Team Leader for the development and manufacture of Rapidly-Manufactured UNZA Mechanical Ventilator Prototype as a response to the Covid-19 pandemic. He has been a Principal Research Supervisor and Principal Investigator for various Projects since the year 2000 till date.