Exploring the Applicability and Challenges of implementing Industry 4.0 Technologies in the Small and Medium Sized Industries in Kenya

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Abstract
Industry 4.0 is a critical and indispensable aspect of modern manufacturing. Broadly, it entails the integration of Cyber-Physical Systems (CPS) and the Internet of Things (IoT) with traditional manufacturing units to yield smart factories. Key benefits include increased automation, flexibility and customisation; vertical and horizontal integration of manufacturing units; effective management of supply and distribution chain; manufacture of smart products with high quality; reduced lead times; better interoperability between design and manufacturing as well as effective decision making through artificial intelligence and big data analysis.

The Micro Small and Medium-sized Enterprises (SMEs) provide 80% of employment to Kenyans and account for 98% of all businesses. The transition to industry 4.0 will have a significant impact on them if they cannot compete with multinational companies. Using qualitative data analysis, key aspects and challenges of SMEs were analysed with regards to industry 4.0. The results indicate that SMEs lack knowledge, autonomous machines, capital, and information technology facilities. While SMEs may not fully realise the benefits CPS soon; phased implementation is beneficial in the short run and acts as an incentive to further developments. A vendor-based model such that a vendor provides industry 4.0 services to SMEs at a fee is proposed and analysed.

Keywords: Industry 4.0, Small Medium Enterprises, Cyber Physical System, Internet of things, Smart Manufacturing, Robotic, Flexible Manufacturing Systems

1 Introduction

Industrial 4.0 or the fourth industrial revolution represent a major paradigm shift from the previous industrial developments and is touted as the future of manufacturing (Liu & Xu, 2017). The 4th revolution combines the power of computer processing, advanced information technology with intelligent machines and robots (Pereira and Romero, 2017). It is expected to transform the industrial sector by integrating manufacturing activities with cloud computing, digital solutions, big data analytics, robotics, and Augmented Reality (AR). Cyber-Physical Systems (CPS) are at the heart of industry 4.0 and are comprised of a system that gathers real-time data, transfers this to a digital platform where decisions are made and these are relayed back to the machine tools as commands to control the manufacturing processes (Wang *et al*., 2016; Dalenogare *et al*., 2018).

Once implemented, industry 4.0 enables mass customization due to flexible manufacturing systems and thereby delivers end-to-end engineering as well as greater customer participation in the design and product development (Wang *et al*., 2016). Vertical integration is achieved through the combination of subsystems within an organization resulting to reconfigurable machines and equipment's that communicate and coordinate to produce different products under an Enterprise Resource Planning (ERP) system (Dalenogare *et al*., 2018). Horizontal integration is achieved when intelligent machines in different organizations communicate and coordinate manufacturing processes autonomously (Liu & Xu, 2017; Fonseca *et al*., 2018). Automated processes increase production efficiency by 40-45% since machines operate autonomously without human error (Wang *et al*., 2016).

While developed nations have laid proper plans to implement industry 4.0 such as Germany's Industrie 4.0/high-tech strategy 2025 which pioneered this technology, Made in China 2025, Make in India, Society 5.0 in Japan and Manufacturing USA; developing countries are still far behind in terms of industrialization and even lack a well-established communication system to support Industry 4.0 infrastructure(Wang *et al*., 2015; Kamble *et al*, 2018). In Kenya, SMEs relies on basic hand tools and intensive human labor for production. Successful implementation of Industry 4.0 by multinational organizations and globalization will result to intensive competition which has big negative impact on local SMEs.

This paper critically evaluates the requirements of industry 4.0 against Kenya's SMEs resource potential to identify potential gaps in implementing the technology. A vendor-based model, to enable Kenyan based SMEs leverage some, if not all, the benefits of industry 4.0 is developed.

2 Methodology

The qualitative research methodology was applied as most peer-reviewed articles on industry 4.0 provide exploratory information (Creswell & Creswell, 2018). Data was collected from credible peer-reviewed publications in Scopus, Science Direct, Google Scholar, Emerald Insight, and IEEE databases. A total of 50 articles, sampled from a set of 130 articles were reviewed. The inclusion criteria were articles with keywords industry 4.0, key enablers, barriers, smart factory, Internet of Things (IoT), critical success factors, dimensions, components, models of industry 4.0. SMEs data was collected from the Kenya National Bureau of Statistics 2016 baseline survey on SMEs and other local sources (KNBS, 2016). Data were analyzed using qualitative techniques.

3 Results

Table 1 below shows a cross tabulation of the main requirement of industry 4.0 and challenges faced by SMEs regarding these requirements.

Table 1: Analysis of industry 4.0 requirements against Challenges faced by SMEs

Requirement	Details and requirements	Challenges Faced by SMEs
Knowledge, training, and skill development	Continuous training on industry 4.0, use of smart devices, CAD systems, simulations, IoT and other components of CPS.	SMEs owners and operators have limited knowledge. No documented training on Industry 4.0. Few owners have attended ICT trainings.
Sensors and signal conditioning	Motion, video recorders, vibration, ultrasound, level, temperature, vibration, ultrasound, pressure, infrared, proximity, video, among others.	Most machines tools used by SMEs have no automation and sensors feature. Most SMEs rely on hand tools. Where machine tools exist, they are manually controlled.
Machines / automatic machines/ robots and other manufacturing systems	CNC lathe, milling, shaper, drilling, sheet cutting machine, punching, gear making machines and other manufacturing machines etc	Most SMEs rely on hand tools and simple machines. Production machines are manually operated with limited automation, robots and automated machines are expensive and not affordable
Energy requirements	Industry 4.0 require stable, reliable, and cost-effective electrical energy on a 24-hour basis.	Energy is still expensive. Government committed to reducing electricity cost and adoption of renewables
Communication infrastructure	Fibre optics communication, Wi-Fi, high speed internet services and cellular network.	Fibre optics infrastructure is currently being installed and expanded in Kenya, the communication infrastructure is rapidly developing and can support Industry 4.0.
Cloud computing and cloud-based solutions	Big data analytics, ERP systems, internet services and connectivity, storage databases and IT management.	Available and offered by many vendors in the country. However, SMEs owners lack awareness and specialized training on how to access and use cloud-based solutions and analytics.
Cyber Security Systems	Involves applying systems that protect data and other processes running in industry 4.0 framework/ a good cyber security is mandatory for industry 4.0	Generally, there are many companies providing cyber security products in Kenya. However, they are not affordable to SMEs, lack of awareness among SMEs and there is limited use since most SMEs do not have computers, digital equipment's, or databases.

4 Discussions

The Kenya SMEs sector employs over 80% of all the working population and represents 98% of all the businesses in the country (KNCCI, 2019; KNBS, 2017). They are a critical driver of the economy contributing 34% of the annual GPD (KNCCI, 2019). Table 1 presents key requirements of the new system in relation to the challenges faced by SMEs.

4.1 Knowledge and skills

The attainment of knowledge and skills in multi-disciplinary areas of industry 4.0 is imperative for successful implementation (Moldovan, 2019; Kiel *et al*. 2017). Key skills include computer literacy, ICT, electronics, mechatronics, optimisation, mechanical and electrical engineering, cybersecurity, software development, simulations, digitization processes, problem-solving, knowledge on ERP systems, CAD/ CAM systems, applications of big data analytics and artificial intelligence, robotics and cloud computing (Kiel *et al*., 2017). Soft skills encompass project and time management, leadership, design and innovation, communication, understanding national and international languages, decision making, developing competitive strategies, bookkeeping, among others (Moldovan, 2019; Sousa *et al*., 2018). Considering licenced SMEs, only 33.3 % have a post-high school education and hence more exposed to technical and managerial skills to run a business but no training on industry 4.0. While 42.3% have received some training on the use of IT; there is limited application of ICT equipment for business activities with mobile phones (40.7%), computer (9.5%) and tablets (1.2%) be the most used devices.

To bridge the gap, trainers must provide basic practical training to technicians and craftsmen. This should be followed by more advanced courses that introduce Industry 4.0 concepts and their applications. Such training can be achieved through work-based study, vocational training, short courses on industry-specific software's. Since most models and knowledge on Industry 4.0 emanate from university-based research; collaborations between industry, academia, and the government is essential in the gradual and phased implementation of the new digital paradigm (Sousa *et al*. 2018; Horvath *et al*., 2018).

4.2 Physical infrastructure

Lack of equipment and the physical infrastructure to implement industry 4.0 is perhaps the greatest challenge facing SMEs. Most SMEs rely on simple hand tools and manually operated machine tools with very low levels of automation (KNBS, 2016). Industry 4.0, on the other hand, proposes the use of robots, autonomous machines, and highly complicated and interlinked factories (Wang *et al*., 2016; Liu & Xu, 2017). These are expensive and not affordable.

4.3 CAD/CAM Systems and Interoperability

The implementation of industry 4.0 cannot be achieved without establishing appropriate interoperability between CAD/CAM systems. Clients and engineers collaborate in the design process producing CAD drawings which are interoperable. These are then changed to machine-readable instructions without loss of data. This requires that engineers, employees, and clients have a high level of digital maturity and understanding (Horvath *et al*., 2019). This can be achieved through exposure to digital platforms as well as continuous training in graphic design and drawing. Kenyan based SME's however lack basic ICT equipment (*only 9.5 % and 1.2% use computers and tablets respectively),* knowledge on advanced design and drafting software and basic literacy skills. Most drawings and fabrication done by SMEs do not conform to national and international standards (KNBS, 2016).

4.4 Internet, cloud computing, and big data analytics

Cloud computing is operated as an on-demand service to subscribers (García *et al*., 2018). Services range from data analysis, networking, data storage, artificial intelligence among other services. There are numerous international and national companies offering cloud-based services in Kenya. The increasing ability to access the internet via broadband, Wi-Fi and cheap data-bundles for mobile phone internet access offered by telecommunication companies represent a great leap by the country in achieving faster, cheaper and more reliable access to cloud-based solutions. Kenya Ministry of ICT has many initiatives to support digitization, growth of the internet and cloud-based services. These include the national optic fiber backbone project that seeks to connect all 47 counties, ICT standardization, digital literacy program,

use of E-citizen and mobile-based payment for government services and the 630-kilometre high-speed fiber optic cable, at Nadapal (Ministry of ICT, Innovation and Youth Affairs, 2020).

4.5 Policies and Implementation Frameworks

The adoption of industry 4.0 implementation framework and policies in developed and developing countries differ considerably (Bogoviz *et al*., 2019). In the developed countries, there are national wide policies and frameworks for industry 4.0 implementation (Kamble *et al*, 2018). In the developing economies, most initiatives are not national but implemented at the corporate level (Bogoviz *et al*., 2019). This is because most lack of institutional capacity, key competencies, and financial backing by relevant public bodies to formulate and implement appropriate strategies. In Kenya, the Kenya Association of Manufacturers in collaboration with oversees development institute (ODI) developed a 10-point strategy in expanding manufacturing in Kenya and increasing jobs using industry 4.0 framework (Banga & Velde, 2018).

5. Recommendations

Acknowledging that SMEs have serious funding issues, lack basic literacy skills as well as the physical infrastructure to implement industry 4.0; it is proposed that a vendor-based model best suits the SMEs sector for implementation of industry 4.0. Rather than full implementation of industry 4.0, a phased approach with smart factories connected with clients, engineers and SMEs is proposed. Figure 1 below shows a schematic diagram of the system. In this diagram, the vendors are either the national or county government, foreign or local private investor or a private-public partnership (PPP). Several vendors provide industry 4.0 services such as cloud computing, internet services, big data analytics, AI, autonomous machines, robots, software, and simulation packages. Engineers assist SMEs and their clients in the design, simulation, and conversion of CAD drawing to CAM codes. This is followed by production using autonomous or semi-autonomous machines. The vendors charge the SMEs for each service used (Müller, 2018). This could be based on *pay – use* model where the SME pays for service before using, *a pay-as-you-go* model where the SME is charged as they use the service or the conventional *subscription model* where SMEs are actively registered to use vendor services. This model could be used by millions of Kenyans without the requirements for any initial investments and thus promote more youths, jobless Kenyans, and unlicensed SMEs to actively compete with a large organisation as well as multinational companies. Currently, the ministry of industrialization has established 165 Constituency Industrial Development Centers (CIDC) centers where SMEs and youths can fabricate and physically produce goods at a fee (Ministry of Industrialization, Trade and Enterprise Development, 2020). These centers have tools for carpentry, metal fabrication, automotive and construction. Such an infrastructure could be expanded to industry 4.0 production and service centres.

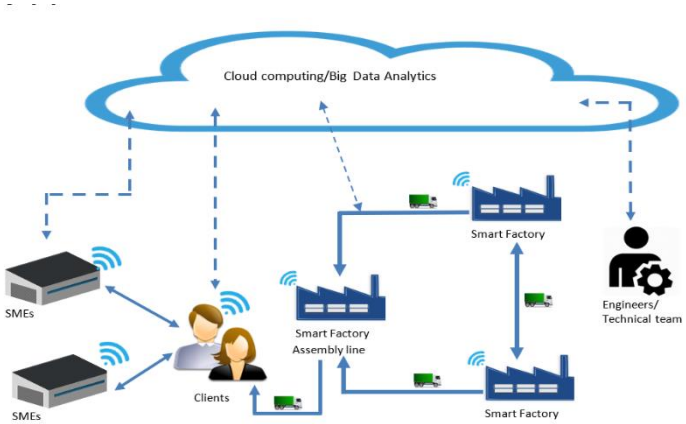

Fig 1: Proposed vendor-based model

6 Conclusions

Industry 4.0 has received considerable attention from developed countries as the next frontier in manufacturing and will result to increased production efficiency, manufacturing process optimization, increased flexibility, create more jobs and allow for vertical and horizontal integration of firms. It will also result in high competition both locally and internationally. Developing countries, like Kenya, need to explore ways of implementing this technology or risk being left behind. While SMEs in Kenya account for 98% of all business activities, they face numerous challenges such as lack of machines, energy, ICT equipment and knowledge which makes them disadvantaged to implement industry 4.0 technologies. This work proposes the use of a vendor-based model which bridges the knowledge, equipment, and infrastructure gap faced by SMEs in implementing industry 4.0. Using the model, the vendors establishes the regional smart factories that charge a fee to SMEs to use these facilities and other services.

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