Positioning the Nigerian Engineering and Construction Industry in the Fourth Industrial Revolution

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Abstract-The Fourth Industrial Revolution, a term coined by Klaus Schwab, founder and executive chairman of the World Economic Forum, describes an era marked by breakthroughs in emerging technologies in fields such as robotics, artificial intelligence (AI), nanotechnology, quantum computing, biotechnology, the Internet of Things (IoT), fifth-generation wireless technologies (5G), 3D printing, renewable energy, and fully autonomous vehicles. New technologies such as Building Information Modelling (BIM) are giving architects, engineers and contractors a completely different perspective on how to optimize the design, construction and operation of infrastructure. Disruptive technologies will present a challenge to the construction industry, which will have to adapt to very different ways of working, but the potential benefits to society could be enormous. This paper discusses the features of the Fourth Industrial Revolution and suggests recommendations to speed up innovation, minimize environmental risks and increase the positive impact of the Fourth Industrial Revolution technologies for the Nigerian Engineering and Construction Industry.

Keywords: *Fourth Industrial Revolution, Artificial Intelligence (AI), 3D printing* technology, Internet of Things (IoT), Nanotechnology

1. Introduction

The First Industrial Revolution used water and steam power to mechanize production. This gave way to the Second Industrial Revolution, which used electric power to create mass production, and then the Third, which used electronics and information technology to automate production. The Fourth Industrial Revolution (4IR) is taking automation to new levels, distorting the lines between the physical, digital, and biological spheres and using technologies to perform tasks previously carried out by humans, ranging from piloting vehicles to 'rules-based' jobs in all areas of life, such as healthcare, wellbeing, business and law. When compared to previous Industrial Revolutions, there exist key differences between the 4IR and the other three. It is characterized by emerging technologies such as artificial intelligence (AI), robotics, the Internet of Things (IoT), big data, cloud computing, autonomous vehicles and drones, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and so forth (**Schwab, 2015**). In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before.

The 4IR is not merely a continuation of the Third Industrial Revolution but rather an innovative and distinct revolution. It represents a paradigm shift with a new wave of innovations characterized by the digitalization of businesses, society and our lives.

2. The Engineering and Construction (EC) Industry

On its own, the Construction Industry plays a key role for governments in both developed and developing economies. The Industry creates new jobs, drives economic growth, and provides solutions to address social, climate and energy challenges. The Construction Industry is prominently linked with other sectors, and its impact on GDP and economic development goes well beyond the direct contribution of construction activities (**Castagnino et.al, 2018**). The Industry is so crucial that the World Economic Forum (WEF) established the Future of Construction Initiative in 2015. Since then, the Initiative has successfully served as a platform for the WEF partner firms, governments, academia, and civil society to shape the Industry's

agenda and to find innovative solutions to support the Industry's transformation and thereby achieve higher productivity, greater sustainability and enhanced affordability.

Part of the agenda of the WEF for 2018-2021 (Phase 4), in collaboration with Oxford University and other partners, is to form a central platform to exchange best practices and ideas guiding the construction industry in its necessary transformation by scaling the Engineering and Construction (EC) ecosystem beyond the existing major players and include key disruptors, creating and implementing policy reform and system transformation (**World Economic Forum, 2019**). The WEF is trying to provide the central leadership needed to position Engineering and Construction in the Fourth Industrial Revolution.

3. The Engineering and Construction (EC) Industry and the Fourth Industrial Revolution (4IR)

The Fourth Industrial Revolution (4IR), or "Industry 4.0", will see construction coming in line with more digitally developed industries. This will revolutionize not only how physical structures are designed, built and maintained, but also how they are subsequently used. "Construction 4.0" is essentially the Engineering and Construction (EC) Industry's version of Industry 4.0, a move towards greater digitalization. It encompasses stuff like prefabrication, automation, 3-D printing, virtual reality, drones, sensors, robots for repetitive or hazardous processes, and data used to help the Industry shape the decisions it makes today and tomorrow.

"Construction 4.0" is still in its very early stages and the construction sector still lags significantly behind other industries in terms of the automation of processes and the level of digitalization. All in all, the Industry is certainly moving in the right direction. We have seen advancements in the digitalization of the supply chain and associated processes such as workflows and approvals. We are now seeing more digital skills coming into the EC Industry. Companies are starting to see the opportunities that technology brings to reduce wastage and duplication as well as control quality, time and budget on projects (**Anyaeji, 2016**).

The 4IR is definitely here to stay, and the EC industry needs to urgently embrace new innovations and technologies for the following reasons:

i. New technologies such as Building Information Modeling (BIM) are giving architects, engineers and contractors a completely different perspective on how to optimize the design, construction and operation of infrastructure. BIM is an intelligent 3D-based process that gives architecture, engineering and construction professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure. Better project coordination and collaboration with stakeholders, efficient workflows, 3D visualization, and the resulting improved project outcomes are some of the benefits of using BIM processes. The notion of creating a "digital twin" of a building or piece of infrastructure is central to Construction 4.0 and enables accurate, well- informed decisions to be made throughout the lifecycle.

ii. There is potential for digitalization to significantly shorten construction times and cut the cost of building new infrastructure. This technological leap in infrastructure construction will be hugely important because of the urgent need to respond to global megatrends, particularly urbanization and decarburization. There has to be greater efficiency in terms of speed and cost of construction because we are in a race against population growth in cities and climate change. The prospect of faster implementation of major projects and lower construction costs is a tantalizing one for policymakers looking to deliver better value infrastructure.

iii. Artificial Intelligence (AI) will transform project management. Project schedules will adjust themselves automatically according to the availability of labor. In the event of an

absence, AI will be able to transfer a task to the individual best qualified for that job. AI will also be able to support engineering decision-making, verifying the design and implementation phases of a project and using data from past projects to provide advice. This means engineers will be able to make evidence-based decisions with a high degree of certainty.

iv. In the next two decades, we will witness a massive transformation where buildings will be first built virtually and the use of machine learning application and autonomous construction equipment might replace most manual work throughout the construction value chain. The business will largely move to advanced manufacturing processes to prefabricate modules that are later assembled on-site, keeping the industry guarded to meet tough environmental regulations through the use of renewable resources. A large chunk of construction work will be fully automated from technologies that include building information modeling (BIM), prefabrication, wireless sensors, automated and robotic equipment, and 3D printing. These disruptive technologies will present a challenge to the construction industry, which will have to adapt to very different ways of working.

v. The economic and social impact of digital technologies such as BIM, prefabrication, wireless sensors, 3D printing, and automated and robotic equipment, can be substantial given that the EC Industry accounts for 6% of global GDP. Within a decade, full-scale digitalization could help the industry escape its decades-long stagnation and generate an estimated 12-20% in annual cost savings, according to the Boston Consulting Group (**Manley et. al, 2017**)

4. How the Construction Industry can thrive in the 4IR

Players along the construction value chain need to prepare strategically to thrive in the face of anticipated disruption. Based on global trends, several scenarios were created by the World Economic Forum (WEF), together with 30 companies, for how the Industry could look in the future (**World Economic Forum, 2016**). They clearly show that existing capabilities, business models and strategies will not be sufficient for success. The scenarios also pinpoint several common moves that companies should take to remain relevant. According to Luis Castilla, the CEO of Acciona Infrastructure and champion of the World Economic Forum Future of Construction Initiative (**World Economic Forum, 2019**) "the Construction Industry's decision-makers should understand the disruption outlined in the future scenarios as a wake-up call. They should use the identified key actions to prepare and shape a prosperous future that will allow the Industry to fulfill its role in promoting economic growth, social progress and environmental sustainability".

The key conclusion is that businesses must act now to circumvent future disruption. Dramatic changes in the horizon indicate an uncertain future for the global industry and its more than 100 million employees.

The following actions will be relevant:

i. Attract new talent and build up the required skills:

Any future scenario requires talent with substantially different skills than today's workforce. Adequate up skilling processes are largely not in place. By 2021, the Fourth Industrial Revolution will have brought us advanced robotics and autonomous transport, artificial intelligence, machine learning, advanced materials and biotechnology. These developments will transform the way we live, work and relate with one another. What is certain is that the future workforce will need to align its skillset to keep the pace. As machines take over technical operations, the EC organizations will begin to place greater

value on soft skills and competencies for managerial and leadership roles that cannot be performed by machines.

ii. Integrate and collaborate across the Construction Industry's value chain: -

The Construction Industry is characterized by a disintegrated and highly fragmented value chain, which hampers the seamless data flow and integrated systems that are essential in any future scenario. Industry 4.0 is underpinned by cross-industry trust and collaboration. Geospatial engineers, surveyors, designers and contractors will need to come together, freely exchange information and collaboratively solve issues as they occur, to maximize the benefit of free-flowing information. For instance, regular ongoing digital data capture and validation procedures of on-site conditions allow project teams to identify discrepancies between design intent and the actual construction. Any disparity can be captured and fed back into the project's digital environment to allow designers and contractors to assess and make informed, real-time decisions on remedial action, thus preventing costly mistakes from occurring.

iii. Adopt advanced technologies at scale: -

The Construction Industry has been slow to adopt new technologies. It still relies heavily on manual labor and mechanical technologies, resulting in poor productivity. Mobile Internet and cloud technology are already impacting the way we work. 3D printing and advanced materials are still in their early stages of use, but the pace of change in fast and reckless.

iv. Maximize the use of data and digital models throughout processes: -

A key component of Industry 4.0 is digital data. With increased access to accurate real-life data throughout all stages of an asset's lifecycle - from design through to construction and maintenance - time and cost efficiencies can be found and errors reduced. The benefits of digital data are already being seen to a degree through the initial adoption of BIM, in which digital assets are created to represent the built environment based on real-world data. With comprehensive geospatial knowledge of the intended site, alongside the stream of digital data captured on-site, errors and delays do not need to be inevitable.

v. Review existing practices and infrastructure asset portfolios, to embrace new business opportunities and enable change management.

5. Conclusion

Technologies of the Fourth Industrial Revolution can offer new tools for city authorities, private developers and residents to properly plan, visualize and manage urban development and operations (smart planning and construction). Drones, sensors and big-data powered simulations aided by artificial intelligence can simplify these processes and improve engagement with citizens leveraging new ways of generating and using data. BIM, advanced materials, 3D printing and artificial intelligence can support intelligent building design and streamline construction contracting. Other solutions include next-generation building codes using digital design and nano-materials to radically reduce embodied carbon in production, and off-site pre- and modular fabrication improving construction efficiency and flexible, reusable building parts.

To build digital awareness (and use) among citizens, as well as to counter the negative effects of automation on jobs, urban and national governments must promote skills and re-training with emphasis on sustainability. If Industry 4.0 is to be achieved, EC companies need to ensure that members of staff have the right expertise and culture. Advisory bodies made up of Industry representatives, promoting how digitalization will enrich the sector and providing practical

advice on how to work collaboratively with new technologies, could help drive Industry 4.0 forward.

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