Essential Skills Towards Fostering Innovation in the Built Environment: A Theoretical SDG 9 Outlook

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ABSTRACT

The built environment has been slow in adapting innovative technologies and methods, and there has never been a more inspiring time to innovate than now. We live in a new automation era in which computers, robotic technologies and artificial intelligence will increasingly perform routine manual work and rightfully take traditional jobs from humans. This technological impact and socio-economic disruption in the industry will transform the employment scenery and skills requirements. This review notes the greater challenges faced by the construction industry in fostering innovation. These include both industry-specific challenges and the need to fulfill sustainable development goals. In addition to these challenges, the need for construction role players to understand the critical skills required for industry 4.0 is also discussed. The study is conducted by critically reviewing the literature of selected papers from well-known academic journals in construction and 4IR research. Above innovative leadership, different innovative skills are vital to developing and understanding emerging innovative technologies. Skills identified include; Creativity, design mindset, entrepreneurship, critical thinking, social intelligence, digital literacy, leadership and computational thinking. Moreover, industry role players with these skills can help fast-track the need for technological innovation in the construction industry. The study presents a robust background in identifying essential skills research agenda in the built environment that fosters innovation and its adaptation.

Keywords:
Construction, Development, Revolution, Industry 4.0, Skills.

Introduction

The banking sector has effectively taken advantage of the 4th industrial revolution (4IR) by finding technological ways to deal with their ordinary business; along these lines, adding to their profitability, precision, productivity and enhanced consumer loyalty (Teuteberg 2016). Nonetheless, the construction industry (CI), which contributes a huge portion to the nation's GDP, is as yet lagging behind in its technological developments. Shrestha (2011) presented that the slow technological adaptation in the CI, combined with resistance for change by the construction experts, has made the full digital process difficult. The 4IR, or Industry 4.0, is presently under way. Likewise, it is highly unlikely that the South African construction industry (SACI) can stay away from it or escape it. Industry 4.0 embraces artificial intelligence (AI), Big Data, the Internet of Things (IoT), Robotics and wearable technologies.

We stand at the brink of an extraordinary technological transformation that will essentially alter the way people live, work and communicate with one another. Unlike its three antecedents (First Industrial Revolution: steam power and systematization; Second: electricity and mass fabrication; Third: computers and automation), the 4IR stems from a rapid fusion of technologies, as discussed above (e.g. IoT, advanced robotics, 3D printing), new materials (e.g. bio- or nano-based) and innovative processes (e.g. AI), which are affecting every industry and entire production systems (Federal government of Germany 2017). This will certainly have a considerable impact on cities, the construction and employment of technical skills.

It was a noteworthy subject at the previous Sixth Council for Scientific and Industrial Research (CSIR) Conference in South Africa. Much more to these forums it is important to note that, South Africa is underprepared for Industry 4.0

(Crampton 2017). Temidayo et al. (2017) concluded that construction experts in South Africa have low awareness towards 4.0 principles. The progressing industrial change keeps on producing an unfaltering interest for specialists with progressively modern technological abilities and skills. This procedure is multi-dimensional. Therefore, professionals with exceedingly high ICT skills will be critical moving in the 4.0 future.

According to the EU commission, advanced 4.0 industry skills are currently required in a wide range of work, including the construction 4.0. Muller and Daniel (2017) stated that there is an emerging need to develop the current workforce, particularly in light of the 4IR and the consolidation of the IoT and digital physical frameworks into the modern creation process.

The realm of work from 2020 and beyond will be considerably different from the way we know it today. Therefore, it is crucial for business leaders to understand the major shifts to ensure that they have their skills planning and other strategies in place to survive the commotion of the next five to 10 years (Daniel and Muller 2017). Likewise, the government, the Sector Education and Training Authorities (SETAs) and other policy makers must rethink the skills strategies. According to futurist Jacob Morgan, nations are failing to prepare the workforce for the exponential stride of transformation that will be disrupting every industry in every country and impacting every aspect of how we work and how we live, creating threats and opportunities. Against this background, this study will evaluate the different industry skills relevant for the 4.0 construction era.

1.1 Objectives

The objectives of the study are as follows:

To determine the impact of essential skills in the built environment.
To identify the barriers hindering the adoption essential skills in the built environment.
To determine the benefits of adopting essential skills in the built environment.
To determine the ways of promoting the adoption of essential skills in the built environment.

2. Literature review

2.1 Industry 4.0

In ordinary terms, "Industry 4.0" means the "fourth industrial revolution", i.e. the digitalization of industry, in general. As the 4IR gathers pace, innovations are becoming faster, more efficient and more widely reachable than before. Technology is also becoming progressively connected; in particular, we are seeing a merging of digital, physical and biotic realms. New technologies are supporting societal shifts by having an effect on economics, values, identities, skills opportunities and possibilities for future generations (World economic forum 2017).

There are four main features of Industry 4.0: vertical integration, horizontal integration, through-engineering, and integration of technologies. Vertical integration requires heightened connectivity within the Smart Factory chain, allowing "workshops and manufacturing plants to react quickly and appropriately to variables, such as demand levels, stock levels, machine defects and unforeseen delays". Horizontal integration facilitates networks that create and add value, such as business associates and customers around the globe. Through-engineering is a unique aspect of 4IR that focuses on the entire value chain. In other words, businesses are no longer just looking at manufacturing or an isolated aspect of the production procedure, but rather they are looking at a product from its inception to the closing output and delivery (Herold 2016). This is achieved with new, advanced and enhanced data collection technology, which is the fourth and final characteristic of Industry 4.0. Industry 4.0 also defines the entire life cycle of a product: from idea to development, manufacturing, use and maintenance – and ending on reprocessing of the product (Federal government of Germany 2016). Industry 4.0 was initially developed by the German government to create a coherent policy framework to maintain Germany's industrial competitiveness on the global market. Related terms used internationally include IoT, Internet of Services, Industrial Internet, Advanced Manufacturing and Smart Factory. For better understanding this thought, the enhancement of the Industry 4.0 idea is shown in the Figure 1 below.

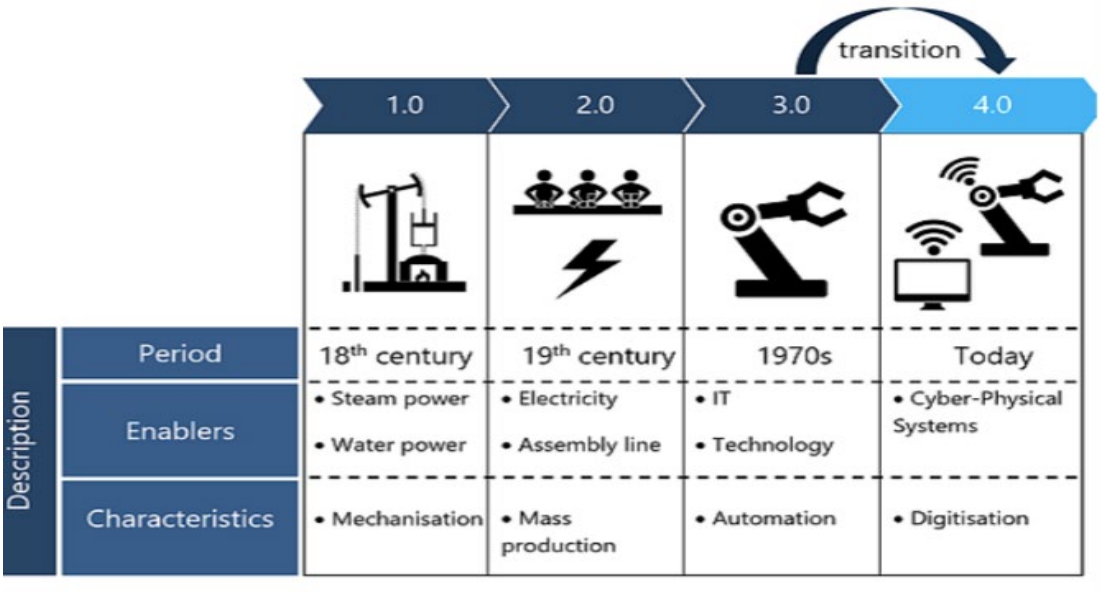

Figure 1. Industry 4.0 concept development (Source: Nowotarski and Paslaski 2017)

According to Zezluka et al. (2017), the first industrial revolution was connected with steam machine development which enabled significant level of mechanisation compared to the previous industry level. 2nd industrial revolution was related to the beginning of the mass production in 19th century with electricity usage and assembly line creation. 3rd industrial revolution was connected with inventing IT and introducing technology into the production as well as the use of automation in processes. 4.0 level can be described as usage of cyber physical systems (CPS) connected with the digitalization and the IoT concept. Development time of the industry 1.0 was vast, as it took ages to invent steam powered machines. Between 1.0 and 2.0 version there were approximately 100 years. Level 3.0 was introduced after 70 years and now the discussion is on 4.0 concept after 30 - 40 years from the last revolution. It has to be noted that in the short time an introduction of 5.0 version of this can be anticipated.

2.2 Digital Collaboration

The term collaboration is well-defined as a joint effort of people or organisations to accomplish a certain goal (Aghimien et al. 2018). The use of collaboration between the construction industry (CI) and digital technology (DT) is geared toward developing the CI more efficiently (Aghimien et al. 2018). Arayici (2015) states that within the latter two decades organizations progress has collected useful DTs in an effort of supporting the ever-growing requests for business competence, effectiveness, quality, and consummation. Digital collaboration (DC) is commonly utilized in big construction and has been used as a link between the sector and technology (McGraw-Hill 2012). Through observing around the world, it has been noted that technologies are being developed, whilst also transforming and revolutionizing all the intricate basic purposes of life. The Architecture, Engineering, and Construction (AEC) industry is no exclusion. As there is no career that can effectively succeed in resolving development challenges within the 21st century without the professional's vision, aspiration, strategy, and mission being fixed in the body of knowledge and tactically driven technology (Halim 2010). The following figure gives an indication of the challenges encountered by construction professionals within the adoption of digital collaboration.

Challenges	Mean	Rank
Lack of training	4.29	1
Expensiveness of digital technologies	4.17	2
Poor adoptability of standards	3.94	3
Challenge of interoperability	3.94	3
Complexity of digital technologies	3.88	5
Increasing complexity of data structures	3.79	6
Diverse nature of systems	3.75	7
Lack of accessibility	3.65	8
Data security and privacy	3.55	9
Satisfaction with existing method of working	3.40	10

Figure 2. Challenges of digital collaboration (source: Emmanuel et al. 2018)

2.3 Impact

You can't hold up until the point when a house torches to obtain fire insurance on it. We wait until there are enormous discords in our society to get ready for the Fourth Industrial Revolution (Herold 2016). Industry 4.0 isn't an envisioned future; it is going on now. The world is putting resources into Industry 4.0, and organizations that don't harmonize 4.0 standards will be left behind. As the fastest-ever period of technological innovation, industry 4.0 creates great promise to leapfrog traditional development and accelerate the transition to a more sustainable urban future. 4IR technologies such as AI, autonomous vehicles and drones, the IoT, advanced materials, 3D printing and biotechnology are particularly relevant. Many are already showing promise at reshaping urban sectors; including transport, energy, waste, water and buildings – and change will only accelerate (WEF 2016).

A report from Cornell University denotes the countries currently leading the 4IR include: Finland, Switzerland, Sweden, Israel, Singapore, the Netherlands, and the United States. Purposely, these countries are recognized for engendering economic impact from investments in information and communications technologies (ICT). Further to note, Industry 4.0 is worth a lot of money. In January 2015, Accenture released a report which established that an industrial-scale version of the Internet of Things, or Industry 4.0, could add $14.2 trillion to the world economy over the next 10 years. The report goes on to emphasize the huge economic growth potential of Industry 4.0, going so far as to state that the value added would not only include monetary benefits, but would be improving worker safety.

2.4 Threats

In 2008 Nicolas Carr suggested that the shifting landscape of modern times is resulting
in a dumbing-down of society because of the over-reliance on technology. Comparably, the movie Idiocracy depicts a society 500 years into the future where “advances” in technology have completely eradicated human intelligence. Although the movie presents an extremely hyperbolic scenario, the pretext for the script is within the realm of believability and raises questions about the true benefits of an enhanced technological age. We must have a comprehensive and worldwide shared understanding of how technology is changing our lives and that of future generations, transmuting the economic, social, ecological and cultural contexts in which we live. WEF (2016) further stated that connecting these 4.0 opportunities and proactively handling these risks will require a transformation of the enabling environment, namely the governance frameworks and policy conventions, investment and financing models, the dominant incentives for technology development, and the nature of societal engagement.

This transformation will not happen involuntarily. It will require pre-emptive collaboration between policy- makers, scientists, civil society, technology victors and investors. According to Herold (2016), Information Technology assumes a basic part in the foundation and upkeep of 4.0. Exceptionally talented information technology personnel should dependably be on the bleeding edge of actualizing and investigating the most recent innovations in this revolution. Moreover, there is insufficient concentrated specialized laborers accessible for the current opening and needs, and even organizations with sufficient technical support will encounter problems in this 4.0 revolution (Zezluka et al. 2017). At the same time, Industry 4.0 creates the challenge of vast job cutbacks; when systems become automated, people will lose their jobs. This however may create a set of new jobs but will be different and highly specialized. Generational gaps also pose challenges as the older generation struggles to survive in a modern digital society.

2.5 Construction 4.0

All over the world, including South Africa, the CI is a substantial sector of the economy that creates job prospects for many citizens and contributes to the country's GDP (CIDB 2011). The Construction industry strongly affects the economy, the environment and society as a whole. It touches the daily lives of everyone, as quality of life is heavily influenced by the built environment surrounding the people. The construction industry serves almost all other industries, as all economic value creation occurs within or by means of buildings or other "constructed assets" (WEF 2016). Associated to many other industries, the construction industry has conventionally been slow at technological development. It has experienced no major disruptive changes; it has not extensively applied advances in processes such as "lean". As a result, efficiency gains have been insufficient. In the United States over the last 40 years, for example, labour productivity in the construction industry has actually fallen. Given the absence in technological growth within the industry, even a small technological improvement would provide substantial benefits for society (WEF 2016).

Lu (2017) stated that, it is not perfidious to say that the construction industry has some challenges to overcome. For centuries the industry has been coupled with delays and unpredicted costs, and the precedent for this has led to these failings being accepted as inevitabilities. Industry 4.0 represents an opportunity to evolve and set a new pattern for what is possible, not what has gone before. BIM is the first step in this development by attempting to create a central repository to assemble digital information about a project or asset. A 2014 EU report advocates the use of BIM use as one of the criteria for the award of public contracts. Likewise, Prefabrication could significantly advance productivity in certain construction areas. Moreover, modularization of buildings could revolutionize the production of building homes and other buildings. Standard elements could be accessible via a "menu" so that some personalization would be feasible. In addition, 3D printing is known to be an amazing new technology, which before was restricted to small components, but can now be used for entire exterior structures. It is exceedingly fast and can be done without any downtime, assuming there are no technical complications.

Construction 4.0 will affect employment. Efficiency is expected to increase, however the effects on the workforce and employability are not yet known. Some well-known tasks may inevitably disappear by and large and it is exceedingly likely that numerous manual occupations will be automated. So, this does not really imply that the "employments" will all vanish. There could be a change in work satisfaction by workers, as a portion of the displeasing parts of their work could be done by a supportive robot, filling in as an acquaintance (Buss and White 2017). It is important to note that the construction industry does not have enough properly skilled specialists in the business if digitalization was to spread rapidly. All things considered, as the aptitudes required in the future are significantly more normal to youngsters, who have been raised on tablets, advanced mobile phones, distributed computing and so forth, there is a reasonable chance to draw in youngsters into the development business. Likewise, there is a chance to draw in more ladies into the construction world who viewed construction as more physical (Lu 2017). Skills significant for 4.0 will be discussed in detail below. The following figure expresses the willingness to adopt construction 4.0 by professionals within the CI.

	Mean	Rank	SD	Standard error of mean	T	Sig (2-tailed)
Smart Construction Site						
Drones	4.40	1	0.856	0.032	7.342	0.000
Prefabrication/Modularization	4.32	2	0.832	0.043	6.708	0.001
Radio Frequency Identification (RFID)	3.98	3	0.732	0.054	5.655	0.000
Internet of things	3.76	4	0.653	0.032	7.478	0.000
Automation	3.64	5	1.210	0.074	10.156	0.000
Product-lifecycle management (PLM)	3.45	6	1.610	0.056	5.754	0.000
Human-computer interaction (HCI)	3.32	7	0.735	0.034	6.100	0.115
Addictive construction	3.10	8	0.652	0.065	6.798	0.000
Robotics	2.70	9	1.345	0.045	5.756	0.000
Cyber-physical systems (CPS) embedded systems	2.65	10	1.562	0.032	4.944	0.120
Simulation tools						
Building information modeling (BIM)	4.40	1	0.734	0.021	6.169	0.000
Augmented/virtual/mixed reality	3.10	2	1.145	0.085	6.354	0.150
Virtualisation						
Mobile computing	4.10	1	0.734	0.092	7.600	0.000
Social Media	3.72	2	0.750	0.045	7.698	0.000
Big data	3.64	3	0.756	0.035	9.432	0.000
Cloud computing	3.50	4	0.632	0.058	8.437	0.000

Figure 3. Willingness to adopt construction 4.0 data (source: Osunsanmi et al. 2020)

2.6 Industry 4.0 Skills

In the journey to adopt Industry 4.0, each country is expected to encounter a number of trials related to the skill level of their work force. The skills which are important today will cease to be so in the future and the work force will be expected to possess new skills in the domain of information technology, data analytics, etc. A higher proportion of the jobs will give importance to cognitive abilities and system skills over physical abilities, while defining core work-related skill sets (Lu 2017). Identifying and recruiting skilled leaders is a primary concern in the 4IR. But where are these trailblazers, and what are the requisite qualifications? Digital skills and industrial know-how remain important, but the soft skills are also of dominant importance. Aulbur et al. (2016), further stated that education and training plays an important role in confirming skill-readiness of the labor force. General education as well as vocational education have a critical role to play in making the labor force 4.0 industry ready.

It is very important to understand what deviations Industry 4.0 will bring in the current construction setup, what the new tasks that an employee will have to do, and how it is going to be different from what he or she has been doing and what additional skills would be required to carry out those tasks successfully. 4.0 will bring higher level of automation and interconnectivity in the industry, thus skills to compliment this level is of importance. According to WEF (2016), these developments will transform the way we live, and the way we work. Some jobs will disappear, others will grow and jobs that don't even exist today will become conventional. What is certain is that the future workforce will need to align its skillset to keep pace. As per the 'Future of Jobs' survey conducted by the World Economic Forum, it is expected that a number of skills that are not considered to be significant in today's context will form one-third of the desired core skill sets of most occupations in 2020. Such a shift in the skill requirement is expected with increased digitalization. The ability to work with data and make data-based decisions will play a major role in the jobs of future (Aulbur et al. 2016).

Skilled labor will have the opportunity to take part in greater task variety and will no longer be associated with only one particular type of job. There will be a significant reduction in monotonous and ergonomically challenging jobs.

Employees will have to share the space with intelligent robots. Assistant systems will support work significantly but the final decisions have to be made by skilled employees.

Team work will be central, not only throughout the horizontal and vertical levels, but also at the actual working place with these assistant systems. Information and data will be the key elements which the employees will have to process in their day-to-day jobs. Artificial intelligence will enable collaboration between humans and machines. And the interaction will not only be limited to pressing or touching buttons, but also by voice and gesture (Daniel and Muller 2016). Employees will use devices like smartphones and tablets for communication and machine operation. New jobs will require the employees to be a part of the planning process and to be involved in process expansion and optimization activities. Employees would be required to do less of manual work and more tasks of control and supervision of the processes. Likewise, creativity, cognitive abilities, system skills and complex problem solving skills are the four skills expected to be high in demand and will continue to remain important. The WEF predicts that more than 35% of the skills considered important in today's workforce will have changed within five years. Some of the new skills that the Institute for the Future identifies as essential for the workplace of 2020 are:

- Novel and adaptive thinking: proficiency in coming up with solutions and responses beyond those which are by rote or rule-based;
- Computational thinking: the ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning in order to make sense of this information;
- Transdisciplinary: literacy in and the ability to understand concepts across multiple disciplines;
- Cognitive load management: "the ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques";
- Virtual collaboration: the ability to work productively and drive engagement as a member of a virtual team; and
- Technological literacy and technical entrepreneurial skills: the capacity for a new partnership with the new smart machines that will enter offices, construction sites and homes.

Employers, SETAs, government and policy makers must heed the warnings of the experts to review South Africa's strategies for preparing the workforce for the 4IR. Change won't wait for us: business leaders, educators and governments all need to be proactive in up-skilling and retraining people so everyone can benefit from the 4IR.

2.7 Sdg 9 Industry, Innovation and Infrastructure

UNDP (2017) states the sustainable development goal (SDG) 9 encapulates three fundamental concepts which outline technology, industrial revolution and infrastructure development.Through the introduction of technological innovations this can be utilised to better instill the need for technologically enclined skills. The need for investment within innovation is crucial in being able to achieve sustainable development. Pradhan et al. (2008); Pisano et al. (2015) sates by observing key components that bring about innovation through developing technology this can assist in the industrialisation process. Through observing the interrelationship between the there components; disruptive innovation, 4IR and SDG 9 are represented as a hierachal relationship shown in figure. The diagram illustrates the interconnection between the three components. Pisano et al. (2015) states that the SDG 9 is a necessary aspect in creating a pathway to industrial development. As a path for industrial develoment is being created the necessary skills need to reflect the advancement of technology. As technology disrupts the old routine of construction practices it is also a breakaway point from the normal mandane ways of executing tasks. The effects of SDG 9 can be achieved by combining skill with contemporary technology (Pradhan et al. 2008; Pisano et al. 2015; Aghimien et al. 2018).

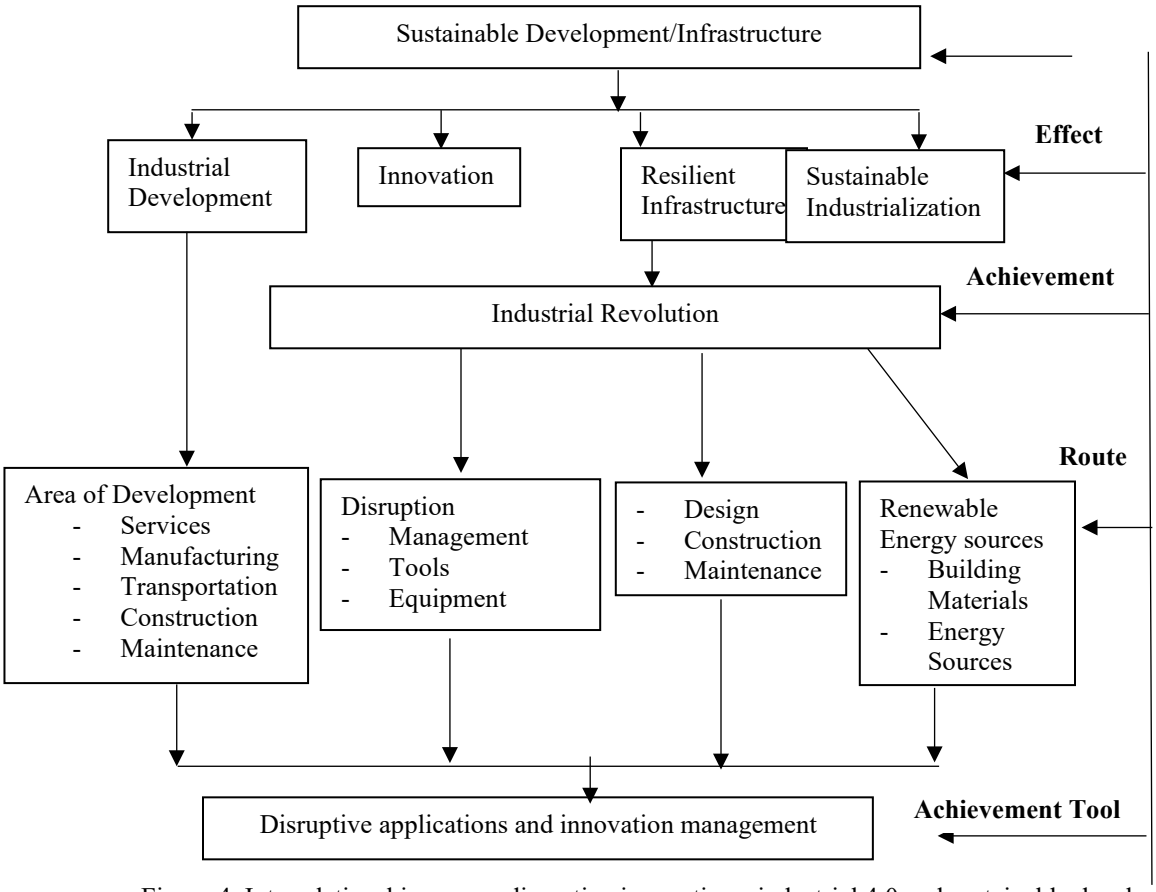

Figure 4. Interrelationship among disruptive innovations, industrial 4.0 and sustainable development goal 9. (Source: Amusan et al. 2022)

3. Methodology

The study is conducted with reference to existing theoretical literature on fourth industrial revolution and the construction industry. The study is mainly a literature review and glances at literature relating to the construction industry towards the fourth industrial revolution. Moreover, the concept of 4IR is a new concept in research and much still needs to examined in this field of array. The current methodology falls within the qualitative research methodology.

4. Results and Discussions

This section presents results and discussions based on the literature review findings. The authors executed a deeper analysis on different publications relating to Industry 4.0 and Construction 4.0, in order to delineate industry skills required for the current revolution. It is important to note that industry 4.0 concept brought about construction 4.0 and it drives the importance for smart construction sites, embrace simulation tools, and virtualization of for construction works. It has been found that the construction industry and stakeholders are not fully ready for the 4th industrial revolution and all the changing work environment it brings. This supports the work by Shrestha (2011) and Lu (2016), who stated that the construction industry faces challenges in adapting to the 4.0 industry. The advantages of effecting industry 4.0 in the construction industry is similar to using it in the banking sector, as indicated by Herold (2016). Different skills will be required for this revolution and it is vital for the construction industry to prepare the workforce for this shift. WEF (2016) opined that critical thinking skills, ICT skills and cognitive thinking abilities are some of the important skills relevant to the 4th industrial revolution. Much to the already existing BIM features ample still needs to be done in upskilling the current workforce in understanding this technology and many other technologies that the revolution brings.

5. Conclusions and Recommendations

The construction industry is one of the most active and receptive industrial sector of any economy. Despite these significance, construction activities are still plagued with traditional approaches and less technological advancement. This is in light of the 4th industrial revolution which is upon us. All Industrial Revolutions have had a profound impact on global society, and Industry 4.0 is no exception. Workplaces are experiencing dramatic transformations unlike anything before, and industries are challenged with recognizing and adapting to these changes. 4IR is particularly unique in the way it challenges current notions of skills development. Review on the current state of knowledge connected to the Industry 4.0 was done and much focus was placed on skills relevant for this revolution, this included digital skills to name a few. The industry including all the stakeholders must regard the call and prepare for 4.0 industry, for the development and advancement of the construction industry. The study concludes that there are different relevant skills that will be required from the workforce, however skilling and reskilling the current workforce will play a critical role in understanding the 4.0 industry. The study recommends that stakeholders in the construction industry should take advantage of this 4.0 industry notion, and create awareness amongst the workforce and professionals, with the purpose of upskilling. It is important for role-players and aspiring leaders to stay abreast of the changing landscape and maintain a progressive approach to guide the industry into the future.

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