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Disruptive technological innovations in construction field and fourth industrial revolution intervention in the achievement of the sustainable development goal 9

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ABSTRACT

Innovation has been described as a vehicle of development. This research therefore address the question of relevance of fourth industrial revolution in providing backbone for disruption that could make sustainable development goal 9 achievable. The purpose of the study is to marry the intervention of disruptive innovation within the context of fourth industrial revolution and how it could help achieve SDG goal 9. Quantitative approach was used in carrying out the research while random sampling technique was used to pick samples randomly across the study area. Sample frame of 100 was picked while sample size of 50 samples was picked from the population frame. Questionnaire designed in Likert scale 1–5 was used for the study. The following results were presented, the need for disruptive innovation in construction field, state of disruption in construction operation in construction industry, factors affecting technological disruption [td], level of awareness of disruptive technology in the built environment, critical success factor in application of disruptive technologies, major drivers of disruptive innovations in construction industry and their functionalities. The study later proposed route for deployment of disruptive application in sustainable construction and achieving millennium development goal through disruptive innovations. Disruptive innovation is the key to desired technological development.

KEYWORDS

Innovation; disruption; building-informatics; sustainability; industry 4.0, revolution

Introduction

Construction industry is a large technical compendium that accommodate allied industries also adding values to various supporting small scale construction enterprises. It consist of SMEs at their various capacity and configurations, Alaloul et al. (2018) described construction industry as wide industry where value adding enterprise takes place, Nowotarski and Paslawski (2017) described construction sectors as a sector that comprise of small medium and large scale construction companies, and as a backbone of economies. Construction industry according to Alaloul et al. (2018) consist of 99.8% of European companies with 6%GDP and employing 70% of total European industries industrial workforce. This is the main reason the industry is the centre point of disruptions by industrial revolution. Construction industry has always the epic of innovative technology, and construction industry, in recent times has become vocal point of attraction all over the world considering the background of various innovative ideas that have been introduced in the form of cutting edge technologies. Alaloul et al. (2018) and Blayse and Manley (2004) opined that construction industry is at the edge of industrial breakthrough, that there have been technologies and innovative ideas that have enhanced construction practices. For instance, Oesterreich and Teuteberg (2016) and Perkins and Skitmore (2015) posited on the advent of productivity enhancement through innovation brought about by industry 4.0 has changed the game through application of conventional tools. Introduction of BIM has produced tremendous impact on building and construction activities, Blayse and Manley (2004) and Shang et al. (2004) argues that innovations have produced tremendous impact on building construction work, motivation and productivity and these had drooped before industry 4.0 and which has been enhanced appropriately. The productivity results in the construction practice through innovation in design and construction of buildings, meanwhile innovations in design, tendering and building construction has changed the route of game in the last few years. Similarly, Huang et al. (2004), Faller and Feldmüller (2015) and Liu and Chua (2016) supported the view that more results have been recorded in the aspect of design actual construction in building and general construction works. However, the innovations being game changer in the building construction and engineering practice, has led to enhanced productivity and saving of a lot of man-hour efforts that could have been wasted, and this was due to application of conventional tools (Perkins and Skitmore 2015).

Also, it was discovered that Introduction of new and conventional tools has accelerated disruption in the administration and performance of previous tools or practice in recent time. For instance introduction of BIM, lean concept and building informatics has produced tremendous impact in design, management and construction of infrastructures (Huang et al. 2004; Faller and Feldmüller 2015). Therefore, the study explored the place of disruptive innovations in the attainment of sustainable development goal in the construction industry using industrial revolution as a

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focal point with a view to achieving sustainable development goal 9. Therefore it was advocated in Liu and Chua (2016) and Wang et al. (2015) an urgent need for introduction of disruptive innovation. Moreover, technological disruption often comes through the fourth industrial revolution, in a bid to create sustainable technological development and sustainable infrastructures. Therefore, there is a need to connect technological disruption, sustainable development and fourth industrial revolution together. It requires identification of the major link connecting them because the three concepts are interrelated and interdependent, it follows 'means' to an 'end' order. The 'means' refers to fourth industrial revolution (industry 4.0), the 'means' is also refer to as the active drivers that leads to an 'end'. An 'end' is the sustainable development, smart and resilient infrastructure, energy efficient 3 D application, infrastructure among others (Huang et al. 2004; Perkins and Skitmore 2015; Tulenheimo 2015). The driver is the fourth industrial revolution that leads to the advent of cutting edge innovation and technology. Therefore, infrastructural development, introduction of innovation and strategies are the pivotal key to achieving one of the sustainable development goal 9 of sustainable infrastructure. However, industrial revolution induces technological development while digitalization of production process is necessary for achieving SDG goal 9, this view was supported by Alaloul et al. (2018), Nowotarski and Paslawski (2017) and Blayse and Manley (2004).

Nevertheless, in order to achieve sustainable infrastructure and technological development, there should be paradigm shift in term of innovation intervention through industrial 4.0. Some parameters are of essence when the issue of mean to an end in achieving sustainable infrastructure of SDG goal 9 arises. Some of the issues include: introduction of exponential technologies for integrating cutting edge technologies, value orientation, value reengineering, terotechnology, vertical integration and horizontal application of disruptive innovation of smart technologies among others this view was supported in Blayse and Manley (2004), Perkins and Skitmore (2015) and Alaloul et al. (2018).

The need for the study

The need to carry out research and study in the direction of innovative disruption in this dispensation cannot be overemphasized. The reason lies in the fact that achieving sustainable development goal 9 is essential towards world industrialization. Also, the content of sustainable development goal 9 is majorly industrialization process and also ingredients to its fulfilment. One of the key components is innovation through technological development (Pradhan et al. 2008; Pisano et al. 2015). Technological development assist rapid digitization of construction process and tasks. It helps to build resilient structures and durable infrastructure. Digitization of component and structures of building is the direction to go in the current technological dispensation. It would assist in building infrastructure that is resilient to forces of time, age, wear and adverse environmental conditions. Digitization brings about as well sustainable self-resilient infrastructure which can only be achieved through disruption of existing technology and methods thereby creating a sustainable infrastructure or system this view was supported in Sindhu Vaardini and Shanmugapriya (2018) who submitted that development goal 9 could only be rapidly achieved through combination of industry 4.0 digitalization and massive infrastructural development. It is to this end that the study attempted at bridging the gap between technological innovation that leads to fulfilment of sustainable goal 9 on one hand and the means to achieving it through disruptive innovation on the other hand.

Literature review

Selected literatures were profiled and presented in this section, they covered aspects of disruption in the construction industry particularly the aspect of informatics. Some issues that relates to construction digitization, strategies of disruptive innovations, innovation in manufacturing industry were reviewed as presented in the few selected literatures.

Sustainable development goal 9

One of the items of agenda in the documentation on 9th position in the United Nation Development programme document for year 2030 that contains detail road map to year 2030, is sustainable development. The 9th goal contains the state of belief of United Nations towards making the world habitable for all and sundry. The goals start 1st with poverty reduction, 2nd Zero hunger, 3rd good health, 4th quality education, 5th gender equality, 6th clean water and sanitation, 7th affordable and clean energy, 8th decent work and economic growth and 9th industry, innovation and infrastructure among others as listed in Pardoe et al. (2018) and UNDP (2017). Also Pardoe et al. (2018) submitted that there should be clear understanding of some ecological and environmental variables such as food, water, energy, infrastructure for adequate positioning and attention in order to ensure their fulfilment, in similar vein, Griggs et al. (2013) and McCollum et al. (2018) supported the view that sustainable development goal 9 contains road map to attaining industrial digital revolution, industrial automation for enhanced productivity, innovation of process and procedure as well as building resilient infrastructure and facility which is also inline in with documentations in SDG Online Library (2018). There are a lot of homeless people all over the world that need shelter and accommodation when there are few accommodation. Thus, there should be an automation process that could lead to mass production of housing facilities. Therefore, there is a need to invest in innovation that would help bridge the digital divide that exists between the masses and infrastructures. Therefore, achieving development goal 9 would open up access to world of digital industrialization that meets the need of present generation without compromising the future. Moreover, the component of the SDG requires integration for successful achievement of SDG goal 9, that is, the three concepts encapsulated in the SDG 9. The concepts include, technology, industrial revolution and infrastructural development (UNDP 2017).

Technological innovations in the form of introducing a technological process or item through new methods of achieving results, is one of the major driver towards achieving technological revolution. This has led to introduction of innovations in recent times, which has changed technological innovation game in different sectors of economy. For instance, there are drones that monitors construction project real time, also there are robots that uses artificial intelligence to plaster and screed floors and various aspect of construction. Similarly, there are machines with sensors and state of art equipment that are in use on construction sites for better delivery and horse power calibration (Griggs et al. 2013; Nilsson et al. 2016; McCollum et al. 2018; SDG Online Library 2018).

Interrelationship and interdependence of the three concepts i.e. disruptive innovation, 4th industrial revolution and sustainable development goal 9 was presented in hierarchal relationship illustrated in Figure 1. The chart in Figure 1 illustrate the interdependence of relationship that exist among the three concepts namely disruptive innovation, 4th industrial revolution and sustainable development goal 9, this view was supported in Pisano et al. (2015) that Sustainable development

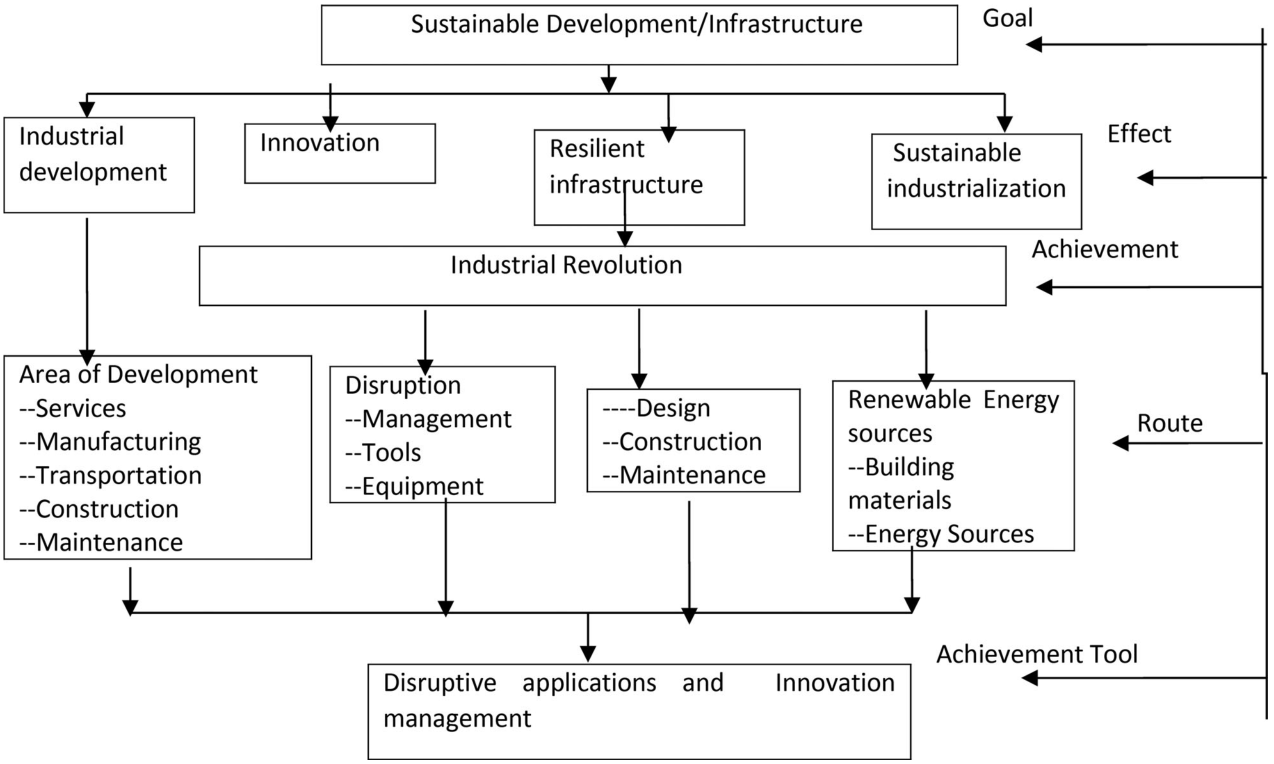

Figure 1. Interrelationship among disruptive innovations, industrial 4.0 and sustainable development goal 9.

goal 9 is an embodiment of the necessity to create pathway to industrial development and is also needed in provision of good and services for economic development. Similarly, in Pisano et al. (2015), SDG was viewed as a Sustainable development goal that was set to achieve technological innovation, infrastructural development and resilient infrastructure. The effect of the goal is to be felt in some areas such as affordable housing, balanced environmental condition, buildings that are resilient to environmental and climatic impact through industrial revolution among others. However, the goal 9 holds an access to positive development in areas such as services, manufacturing, transportation, construction and maintenance. Furthermore, the effect of the sustainable goal 9 could be achieved through conventional techniques that combine skill with contemporary technology (Pradhan et al. 2008; Pisano et al. 2015; Aghimien et al. 2018).

Methods like the following could be used to exploit the sustainable goal 9 which is centred on industry 4.0 technological innovation, for instance exponential orientation could be used in provision of resilient infrastructure and sustainable infrastructural development among other methods. Similarly, value reorientation and engineering would be valuable, when combined further with symmetric parallelism and asymmetric parallelism in innovation of ideas and innovation deployment vis a vis technological transfer and retaining among others this toes the line of submissions in Alaloul et al. (2018), Nowotarski and Paslawski (2017), Blayse and Manley (2004) and Perkins and Skitmore (2015), respectively.

Relationship among disruptive innovations, industrial 4.0 and sustainable development goal 9

Digitalization in construction (establishing awareness and level of technological disruption)

Digitalization has taken the centre stage of discussions all over the world overtime. It has become a global phenomenon, to this end, Aghimien et al. (2018) described it as popular among professionals in construction industry because of its ability to effectively transform operations in the construction field (Pradhan et al. 2017). In his opinion interpreted digitalization adventure as a means of presenting information in a way that bears digital characteristics and nature. Digitalization of items often transfer the digital nature to the original nature of the item (SDG Online Library 2020). On the other hand sees it as a way of transforming information in a way that would be better than the previous format.

Digitalization has however transformed the construction industry landscape, construction cycle has experienced cycles of change in certain aspects of construction work which includes design, planning, administration, personnel training, construction and maintenance aspect of construction (Moon et al. 2016). There is still slow diffusion of digitalization to all aspects of construction works, therefore (Castagnino et al. 2016) advocated effective integration of digitalization in construction industry against the background of the advent of industry 4.0.

Moreover, Experts advocated adoption of digitalization the construction industry, however, Tulenheimo (2015), Pradhan et al. (2017), and among other researchers, carried out a study on Digitization of construction industry. The study identified the requirements for preparing a building for complex disruption to include identifying the building that needs disruptions taking into consideration the key components, setting up key enabler. So also, the construction digitization was adjudged as a catalyst that would facilitate holistic application of BIM.

Similarly, disruption through digitalization requires resources for effectiveness Huang et al. (2004), Aghimien et al. (2018), Pradhan et al. (2017), and (2019) documented their findings on resources that could be used to bring about technological innovations in a disruptive form. Resources like computer applications, soft wares, BIM and non-tangible resources like idea are needed in digitalization implementation. For instance, Pradhan et al. (2017) explored how organization use sourcing for idea and

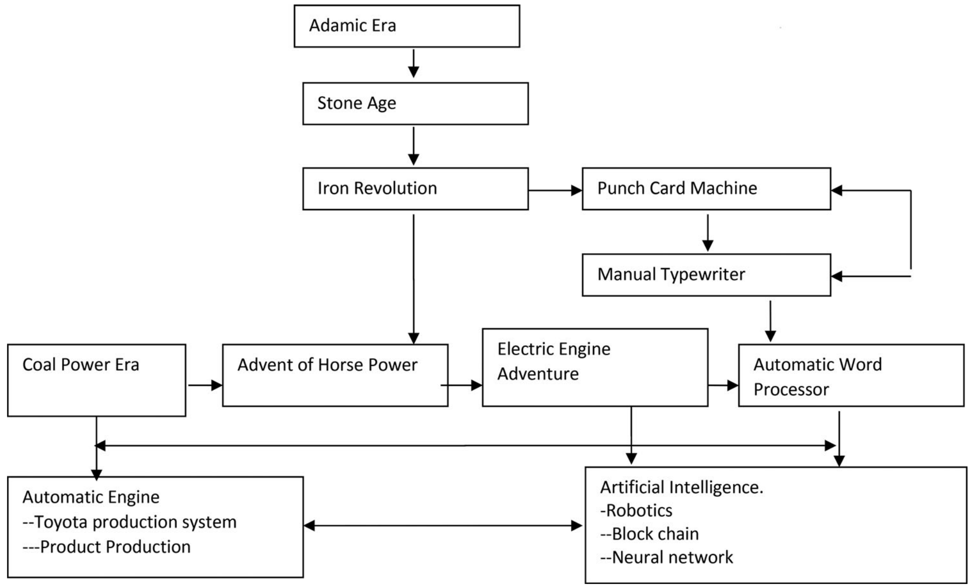

Figure 2. Developmental model of advent of industrial revolution in solving construction problem.

creation of idea versus idea development to bring about innovation in an organization. Taking the conversation further, innovation is often necessitated by challenges or difficulty encountered during the course of developing an idea or problem, it is a general believe that necessity is often the mother of invention. Breaking ice in innovation implementation during digitalization involves identifying an opportunity in the form of a challenge and explore it, therefore innovating solution or new approach to tackling such challenge or problem, disruption often comes in the form of new solution to a problem this was supported in Maresova et al. (2018) and Skibniewski and Zavadskas (2013).

Nevertheless, innovation management is a vital point that need to be seriously taken into consideration, innovation in digitalization process requires setting up research agenda, in line with this school of thought (Faller and Feldmüller 2015), studied research agenda approach to innovative management solution to projects. The study took stochastic approach to project management conceptualization differentiating between project management and innovation. Innovation could be regarded as means to an end but not an end itself. Innovation could be viewed as tool often engaged as at when necessary to generate an enhanced result against background of previous results. Meanwhile, Maresova et al. (2018) and Skibniewski and Zavadskas (2013) supported the view that project management is a field of responsibility where basic tools of productivity are being tested. Researching could also be seen as a panacea to the world of unending innovations, the more research are being carried out, the more likelihood is new discovery thereby innovating new solutions.

Disruptive innovations in the construction sector

Technological disruption could be described as the use of tools, equipment, machines, craft, techniques, methodology and systems to solve problem or provide an improved ways achieving a task. The hierarchy of interdependence of components is depicted in Figure 2, Skibniewski (2014) viewed disruption in construction field as a continuum, that right from early times construction construction industry has been witnessing innovation disruptions. Creativity is a continuous thing and inseparable entity from technology, and most of technology occurred on account of innovation, for instance ancient Greek and Roman Empire was able to improve their construction acumen through knowledge exchange in the field of architecture while perfecting their skills (Skibniewski 2014). Moreover, there are specific strategy that could be used in achieving disruptive innovation, Liu and Chua (2016) studied strategy of disruptive innovation in emerging regional markets exploring the factors of success and failure. The study was devoted to the analysis of structure and how to develop disruptive innovations.

Some of the strategies and factors as detailed out in the gap analysis and objectives iii and iv in this study, which influences failure and success of disruptive strategies outlined in Huang et al. (2004), Faller and Feldmüller (2015) and Liu and Chua (2016) includes step by step analysis of basic requirement, understanding the market trend, creating basis for competitive advantage among others. This fact was corroborated in Wang et al. (2015) and Pekka et al. (2017) where different definition of disruptive innovation and also introduce new dimension in manufacturing was proposed. There should be more study on investment in research and development rather than policy that tends to move manufacturing back to the country of the parent country. Also, concept of technology adoption cycle is important in the study of innovation disruption, for instance Pradhan et al. (2008) carried out a study on Innovations in the construction industry. The study reviewed innovation models and also investigated the concept of technology adoption life cycle. The study proposed a new model of innovation while the model specified the following as the life cycle of innovation adoption; creation of innovation, identifying the need for the innovation, creation of the innovation hall marks, diffusion of the innovation and adoption of the innovation.

Sustainable development goal 9 and relevance of 4th industrial revolution initiative

Sustainable development goal (SDG), specified areas of focus for an effective developmental success in world economy. SDG document specified twenty (20) areas recommended to be covered by year 2022. Also, the content of the goal specified relevant areas that should be accorded priority, they contain specific items that should be covered that would lead to better environment, enhanced environmental function, renewal of environmental functions, sustainable energy production vis a vis its utilization and enhanced technological development among others. This study centred on the achievement of development goal nine (9). The goal specified the need for the introduction of cutting edge technology and achieving millennium development goal through disruptive innovations and industry 4.0 (Pradhan et al. 2008; Sindhu Vaardini and Shanmugapriya 2018).

The need for disruptive innovation in construction field

Achieving sustainable development goal 9

Sustainability is a universal concept that controls people's mentality about securing the present without compromising the future. Sustainability thus thrive on pillars as advocate in Purvis et al. (2019), three pillars were advocated the social, economic and environmental pillars. Similarly, Munasinghe (1993) submitted that development encloses three (3) concept: economic, social and ecological systems. Sustainable economy manages income in conservative way, the ecological system preserves the biological components while social sustainability seeks to present physical system. To this end, Blayse and Manley (2004) reported application of industrial revolution to bring about sustainable development in developing countries using Indonesia as a case study. The study explored the biological and natural component of environment in Indonesia and how to improve them through industrial revolution. The study later advocated the need for sustainable development. Industry 4.0 was seen as vehicle of achieving sustainable development goal (Basiago 1998).

Finally, achieving sustainable development entails the incorporating social sustainability leveraging on the three pillars of sustainability namely, economic, social and ecological pillars. Social sustainability has since 1987 formed an integral part of the study of sustainable development. Vallance et al. (2011) linked the origin of social sustainability to the 1987 Brundland Report, social sustainability was described in the report as an integral part of means of accomplishing ecological goals, taking care of the present while providing for the future generations. In Oesterreich and Teuteberg (2016), importance of ecological and social sustainability was stressed. The study explored industrial 4.0 by evaluating the influence of industrial 4.0 in the context of sustainable SDG Agenda 2030. Industrial 4.0 was regarded as a vehicle for technological innovation, the study listed the ingredients of development as follows: creating vertical technologies, creating value chain, network resurrection of value chain method among others (Munasinghe 1993). In the light of the above achieving sustainable development goal 9 being one of the gaps identified in this study and formed part of objective v, could be realized through manipulating factors around the three pillars of achieving sustainability i.e. focussing on pillars (economic, social and ecological pillars as advocated in Munasinghe (1993), Basiago (1998), Pope et al. (2004) and Eizenberg and Jabareen (2017). Social sustainability creates adaptability so as to enables stakeholders cope with risk and uncertainty. Some of the basic components includes equity, safety, eco-presumptions and sustainable urban forms (Wank et al. 2016; Eizenberg and Jabareen 2017).

Aim of the research

The aim of this study is to explore the impact of fourth industrial revolution using disruptive innovations in the attainment of sustainable development goal 9 in construction industry with a view of providing means of achieving the sustainable development goal.

Establishing research gaps and objectives

In order to situate properly the objectives for the study, few articles were reviewed and summarized, the summary led to the emergence of research objectives. It was discovered in the articles reviewed that majority of them focussed on disruptive innovation in construction industry and production sector, for instance, some of the issues covered in the selected articles include: documentation of technological tools (UNDP 2017), resources for disruptive innovations (Wang et al. 2015; Hughes et al. 2019; Jiao et al. 2019), research agenda for managing innovation in projects (Pradhan et al. 2008), creating future for innovation (Pisano et al. 2015), adaptive disruption in manufacturing (Noor 2009), innovative models (Ally 2019), similarity between innovation and construction (Sindhu Vaardini and Shanmugapriya 2018) and digitization in the construction industry (Ally 2019; Noor 2009; Hughes et al. 2019).

Also, some gaps were identified, which also represents areas that are exclusive to those covered by the scope of the reviewed articles, it also formed part of the research focus of this study, the gaps are: innovation procurement and deployment route, strategies to achieve the content of MDG goal 9 through innovations, drivers and triggers of disruptive innovations, development of framework or model for solving innovation problems and challenges associated with industry 4.0 applications. This study attempted at exploring the disruption of construction industry with new innovation that is traceable to the advent of industrial revolution and how the disruption could help in the achievement of SDG goal 9 with a view to improving performance in construction industry. In the light of the above, the above the following gaps formed the focus of this study, they were the gaps identified in the reviewed articles, they include: innovation deployment route, strategies to achieve MDG, major division of disruptive innovation and development of a model to solve associated problem among others. The study thereafter presented a model that could serve as a guide in the application of disruptive innovation in construction field.

Objectives of the study

In order to achieve this feat, some objectives were formed on account of gaps identified from the few selected works. The following objectives served as a guide to the study, they include:

i. To validate the state of disruption in construction industry in developing economy like Nigeria.
ii. To establish level of awareness of disruptive technology in the study area
iii. To profile factors affecting technological disruption
iv. To benchmark factors that are critical to the application of disruptive technology
v. To propose deployment route of disruptive innovation application to achieve sustainable construction
vi. To establish strategies that could be used to achieve millennium development goal 9 through disruptive technology approach.

Materials and methods

Primary data were obtained professionals of construction at selected locations of the research while Survey materials adopted structured questionnaire design in a closed structure manner as carried out in similar studies such as in Pisano et al. (2015), Sindhu Vaardini and Shanmugapriya (2018) and UNDP (2017).

Material and tools

In the context of this study different materials and tools were used, part of the materials used are A-4 papers for the drafting of questionnaire, audio equipment, markers, pencils and biro. Also, Statistical tools of SPSS were engaged in the processing of data collated from the respondents. Some of the tools include Relative Agreement Index (RAI), Spearman Ranking, Mann-Whitney U-Test, Pearsons's and Student's T-test.

The Relative Agreement Index was calculated using the following relation.

$$RAI = \sum \frac{Wi}{A \text{ x } N} \quad (1)$$

where RAI = Relative Agreement Index, Wi = Weighted Sum, A = The number of items on Likert scale of 1–5.

N = individual weight of the scale item on Likert scale 1–5. The component of the Likert Scale in3lude (SA: Strongly Agree (5), A: Agree (4); SD: Strongly Disagree (2); D: Disagree (1); N: Neutral (3).

R.A.I = 5(SA) + 4(A) + 3(N) + S.D(2) + 1(D)/ 5(SA + A + N + SD + D); where SA = Strongly Agree-5, A = Agree-4, N = Neutral-3, S.D = Strongly Disagree-2 and D = Disagree-1.

Qualitative research approach that involve Survey design method was used in carrying out the research while random sampling technique was used to pick samples randomly across the study area. Sample frame of 150 construction companies was picked while sample size of 100 samples which represents respondents that are construction work oriented was picked from population frame. Questionnaire designed in Likert scale 1–5 was used for the study and distributed to respondents that consist of construction professionals that are actively engaged in the study area. The respondents include construction professionals such as Builders, Architects, Quantity surveying and Civil engineer. The following parameters were censored, profiled and investigated in this study, some of them include: the need for disruptive innovation in construction field, state of disruption in construction operation in construction industry, factors affecting technological disruption [td], level of awareness of disruptive technology in the built environment, critical success factor in application of disruptive technologies, major drivers of disruptive innovations in construction industry and their functionalities, proposed route for deployment of disruptive application in sustainable construction and achieving millennium development goal through disruptive innovations.

Findings and discussion

The retrieved questionnaires were subjected to content analysis for purpose of quality control, the filled questionnaire was checked for consistency, cross validation and filling errors before further analysis. The following parameters were tested in the questionnaire while responses as regard each items were profiled, sorted and presented in tables under subheadings. The tested parameters include: state of disruption in construction operation in construction industry, factors affecting technological disruption, level of awareness of disruptive technology the built environment and framework for drivers of disruptive innovations in construction industry.

Table 1. State of disruption in construction operation in construction industry.

S/N	Destruction parameters	R.A.I	Rank
A.	Design	0.85	2
1	Introduction of AutoCAD application	0.89	1
2	Invention Autodesk Revit	0.83	2
3	Automatic card plotter	0.85	3
4	Electronic Design Graphics	0.85	4
5	Building Modeller and Simulators application	0.82	5
B.	Costing	0.83	3
1	Electronic Cost Component Crawler	0.89	1
2	Electronic taking off sheet	0.84	2
3	Introduction of self-adjustable Bill of quantity	0.83	3
4	Invention of project cost analyser	0.81	4
5	Introduction of Cloud cost storage space	0.78	5
C	Planning	0.92	1
1	Advent of project management software	0.79	1
2	Introduction of E-planners	0.78	2
3	Incorporation of PERT in project monitoring	0.77	3
4	Application of Decision Trees in forecasting	0.75	4
5	Deployment of project life cycle monitoring device	0.75	5
6	Electronic early warning system	0.74	6
D	Construction	0.82	4
1	Robotics application	0.88	1
2	Proliferation of electrical machine	0.83	2
3	Introduction of automatic mechanical tools,	0.80	3
4	Introduction of new techniques in construction operations research	0.79	4
5	Application of Artificial Intelligence and Building Informatics tools	0.79	4

Professionals: Architect, Builders, Quantity Surveyor, Structural Engineer, Planner.

Disruption in construction operation and critical success factor in application of disruptive technologies,

State of disruption in the construction sector was presented in Table 1. Four (4) categories of professionals were used in the study, they include: Architect, Quantity surveyor, Structural engineer and Planners. Average sum of relative agreement index (RAI) for the individual RAI of the professionals were presented in Table 1. Four (4) areas of disruption were profiled, they include: Design, Costing, Planning and Construction. Cross examination of the factors lead into discovery of the fact that within the profiled areas, there is hierarchy. The area rated by the professional as first is construction planning, design of construction project was ranked second, then, area of costing of construction work was rated third while actual construction operation was ranked fourth. Similarly, in planning which was ranked first generally, advent of project management software in the construction industry was ranked first among sub-factors with RAI value of 0.79, introduction of planners with RAI value of 0.78 was ranked second, incorporation of Programme Evaluation Review Technique PERT in project monitoring with RAI value 0.77 was ranked third while application of decision tree in forecasting ranked fourth, alongside deployment of project life cycle monitoring device with RAI value of 0.74 ranked fourth and fifth respectively. Also, design was generally ranked second among the four (4) parameters i.e. design, costing, planning and construction. In the order presented, design of the building should come after various planning that supposed to have been carried out is consummated. Some literary presentations supported the survey above, for instance, Hughes et al. (2019), Jiao et al. (2019) and Noor (2009) submitted that there are different types of planning that could be used, e.g. short term planning, medium term planning and long term planning. With reference to the survey, major area of disruption is in planning of construction works. The truth lies in the fact that there are many innovations and packages that could be used in planning construction works at feasibility and planning stages. For instance Programme Evaluation Review

Table 2. Challenges/factors influencing fourth industrial revolution technological disruptions.

S/N	Technological disruption parameters	R.A.I	Rank
A	Organizational induced factors		
1	Readiness of organization to adopt TD	0.81	1
2	Fear of loss of human capital income	0.81	2
3	Expensive nature of the intended TD	0.79	3
4	Organization policy	0.78	4
5	The need for competitive advantage among competitors	0.72	5
B.	Professional composition oriented factors		
1	nadequate experience about the new technology to be introduced	0.84	1
2	Resistance to imminent change in technological development	0.82	2
3	Level of educational development of construction workers	0.83	3
4	Psychological barrier	0.82	4
5	Demand of the profession	0.80	5
C	construction industry induced factors		
1	Technical know-how of construction stakeholders	0.81	1
2	Readiness to accept the technology	0.80	2
3	Previous experience about the performance of similar technology	0.77	3
4	Suitability of the introduced technology to existing problem	0.75	4
5	Cost of deployment of new technology	0.72	5
D	Internet of things factor		
1	Issues and challenges of Cybersecurity	0.78	1
2	Interoperability of functions	0.75	2
3	Data encryption challenge	0.73	3
4	Issue of data storage challenge	0.70	4
5	Computer literacy issue and challenge	0.70	4

Technique (PERT) and related software are being used at planning stage to prepare feasibility study, time and cost projection, creation of master programme and general construction resources planning and programme among others. However, uncertainty in the performance and selection of innovative systems is often leveraged on certain extreme ideals which tend to classify technology to be used into classes, for instance, technology to be adopted can be classify into high tech, low tech and medium tech innovations, this submission is corroborated by a study carried out by Hughes et al. (2019), Jiao et al. (2019), Noor (2009), Ally (2019) and Anggusti and Siallagan (2018) which in their submissions affirmed that in every economic scenario, project are often classified into various degree depending on project level of complexity, also that projects can be categorized into four dichotomies, i.e. low tech project, medium tech project, high tech projects and super high projects. Technicality involve in a project would determine the level of innovations required or fulfilment of its delivery.

Technological disruption using fourth industrial revolution

Factors influencing technological disruption was presented in Table 2. There are five factors benchmarked and presented in Table 2, the factor/parameters include: Internet of things, construction industry induced factors, professional oriented factors and construction organization induced factors. Professionals in construction organization has always been the active driver in introduction and management of innovations in the construction industry, there are factors that influences the extent of professional contribution as regard the subject matter, it includes: inadequate experience about the new technology (ranked first), resistance to change (ranked second), educational development of the driver of the new innovation and psychological and intellectual barrier among their factors. In relation with Internet of things factor, the following issues are rated high as part of important issues for consideration, cyber security, interoperability of functions, data encryption challenges among others. Also, construction industry has tremendous impact on some few disruptions ever experienced, reasons were suggested for the disruptive trends observed in the industry, and the reasons are listed in the order of technical know-how, readiness to accept the introduced technology by construction practitioners and suitability of the technology to solving current problem in the industry among other factors. In the light of the above, technical education about a proposed innovation is necessary prior to the actual deployment of the innovation.

Similarly, some of the challenges confronting effective diffusion and implementation of disruptive innovation are organizational based, such as, organization readiness to embrace new technology, fear of loss of human capital resources, non-affordability of the cost of the innovation and organizational goal and policy among other reasons. The fact stated above is supported in Hughes et al. (2019) and Evans-Greenwood et al. (2019) and Vertakova et al. (2016) on the need for a necessity to arise in an environment which would lead to innovation. New innovations always have long history that preclude their establishments, for instance artificial intelligence just came to prominence while the early work was carried out by Allan Turin in 1940s. The foundation work on statistical based machine work was laid in the late 40 s, however the impact was not felt until mid-2000s.

Awareness of disruptive technology the built environment

There are several areas that technology disruption manifested during the course of the research work. The presentation was based on the sampled response of professionals such as Architect, Builders, Construction Engineer, Cost expert and Project co-ordinators. The listed areas of disruption as contained in Table 3, are design, costing, planning and project monitoring and control. Builders and Project coordinators indicated as first (1st) among the professionals category, the prominent areas where disruption was observed in construction operations as being design and costing areas of construction operation. Builders operation entails accessing and interpreting project drawing and using cost documents in the execution of construction work, therefore it was adjudged that they would have fair assessment of the situation in consideration, this tend to validate the responses obtained from them.

Pearson's T and Student T test was carried out on mean of responses collated from construction professionals used for the study. The test was carried out to compare the difference in means of the professionals' response on areas of disruption in construction. This is to check whether there variation among the group observed. The test results of equality of variance of means as presented in the table. The test was performed at 95% confidence interval and all variables presented exhibited P-value less than 0.05 i.e. $p < 0.05$. The result statistics implies that there is significant difference in the means value the samples of the professionals, therefore, the Null hypothesis is rejected, implying that there is variation in the mean values of satisfaction level of professionals as regards the rating. The reasons behind the difference could be linked to the background experience of the professionals. Individual respondent can only judge a situation in line with their professional duties, hence the variation observed in the mean between groups.

The areas described in the table above are considered as germane to the success of construction project, this toes the line of

Table 3. Level of awareness of disruptive technology the built environment.

S/N	Professionals	Areas of disruption: Design	Costing	Planning	Project control	Mean	Rank
1	Architect	0.86	0.77	0.72	0.80	0.79	2nd
2	Builder	0.85	0.77	0.80	0.80	0.81	1st
3	Construction engineer	0.82	0.78	0.78	0.71	0.77	3rd
4	Cost expert	0.82	0.81	0.74	0.78	0.79	2nd
5	Project coordinators	0.83	0.80	0.80	0.80	0.81	1st
	Mean	0.84	0.76	0.73	0.72	0.76	4th
	Rank	1st	2nd	3rd	4th		

submission in Saki (2016) and McCollum et al. (2018) and SDG Online Library (2018) which described nine areas of success in construction project management as include integration of different aspect of project, defining scope and limitation of project, time and cost management on project work, managing project schedule, human resources training and sourcing, communication on project and analysis of risk and mitigation effect on project work.

Prevailing areas that need disruption in construction field

There are areas that constantly requires innovative ideas in order to do things in better ways in order to create value for money. Some of such areas include; construction design, construction planning, construction costing and building maintenance as illustrated before in Table 3. There are innovations that are often applied at design phase of buildings, it enables designers overcome some of the difficulties often associated with manual drafting, in term of structure and functionality. Some of the disruptive innovations identified include among many others: Autodesk 360 degree software, Autodesk Revit, Sketch up, Dassault system, BIM among others. In design, Autodesk (3600) software, offers management solutions that affords designers and managers opportunity to be able to monitor design in building process. The software enables the following to be achieved on a project: waste elimination, little or no delay, dual accountability features, enhanced performance and tracking of performance among others (Martino and David 2000; IITA 2015; Amusan et al. 2019a, 2019b).

The application of the parameters listed above has enhanced performance of construction professionals on construction projects. Also, Autodesk Revit, is a building information model-based software that aids speedy designs in building, it offers intelligent platform for design and planning of building. The features incorporated into the software enables interoperability of design information, multidisciplinary approach in design and construction solutions and faster multi-head approach. Moreover, Sketch up is another approach that enables 3 D modelling tools application for solving design-related challenges on site. It enables the user to initiate drawing and draw lines on canvass and sketch to transform design into 3-D formats. Sketch up offers free module, it is available for everyone. So also, in Yamazaki and Maeda (1998), it was supported that Dassault BIM system is also a BIM tool that covers area of design and innovation in construction. It also enables parallel collaboration in project success. The software enables inter-collaboration among project professionals on sites. The software was equipped with built-in solutions for effective project life cycle administration. Moreover, disruptive innovations are available in the aspect of project costing, this has enabled cost expert overcome challenges of ineffective cost capturing overtime, and ineffective cost capturing had been identified as one of the reasons for project abandonment. To this end software like Primus JFC, enables quick development of Bill of quantity, construction estimate and financial advice on a project.

Table 4. Strategies for achieving millennium development goal through disruptive innovations of industrial 4.0.

S/N	Parameters for achieving MDG through disruptive innovation and industrial 4.0	R.A.I	Rank
1	Investing in the innovation in the industry	0.88	1
2	Encouraging infrastructural development	0.87	2
3	Bridging the technological and digital divide in construction sector	0.87	2
4	Developing sustainable construction SME	0.87	2
5	Encouraging scientific research in construction sector	0.84	3
6	Innovative ideas that encourage construction sustainability	0.83	4
7	Setting up framework for disruptive innovation engagement	0.82	5
8	Developing strategy for technology transfer	0.78	6
9	Setting up of monitoring and control mechanism while disruption lasts	0.73	7
10	Developing mechanism for continuous review of progress achieve	0.71	8

Application of disruptive technologies

There is often catalyst that accelerate development in organization and systems. The catalyst could be classified as factor that influences success often described as critical success factors. The factors often presents systematic step by step conditions that predicates success in an endeavour. In the context of this study, some parameters are articulated as being critical to the successful deployment and application of disruptive technology. Some of the factors include among others presented in Table 4; Establishing the need for the disruption (ranked 1st), Locating areas where disruption is needed (ranked 2nd), Rightly instituting methodology to use for the adoption (ranked 3rd), Identifying possible constraint and hindrance (ranked 3rd), Personnel training and retraining (ranked 4th), Setting up good remuneration and reward mechanism (ranked 5th), Effective monitoring and control system (ranked 6th) and Consolidating progress achieved and forecast towards enhanced performance (ranked 6th). However, the highly rated factor is establishing the need for the disruption as well as locating areas where disruption is needed, necessity is often the driver of any invention, and therefore identifying the need for disruption would be a pointer to the innovation needed. This fact toes the lines of submission in Perkins and Skitmore (2015) which submitted that technology that add value in term of solving people's challenges would be in high demand by the people. As reflected in Figure 3, establishing the need for introduction of a disruption should be user's-opinion oriented, in this manner, technology tends to assist people in getting improved business transaction, lower data or subscription charge, access to internet tools helps business development and growth.

Deployment of disruptive application in sustainable construction

The proposed route for deployment of disruptive technical innovations was presented in Figure 4. The order of the application is structured in a way that arranged the order of implementing the technological application in the correct order. The first step is need identification which was ranked 1st, the next step is to

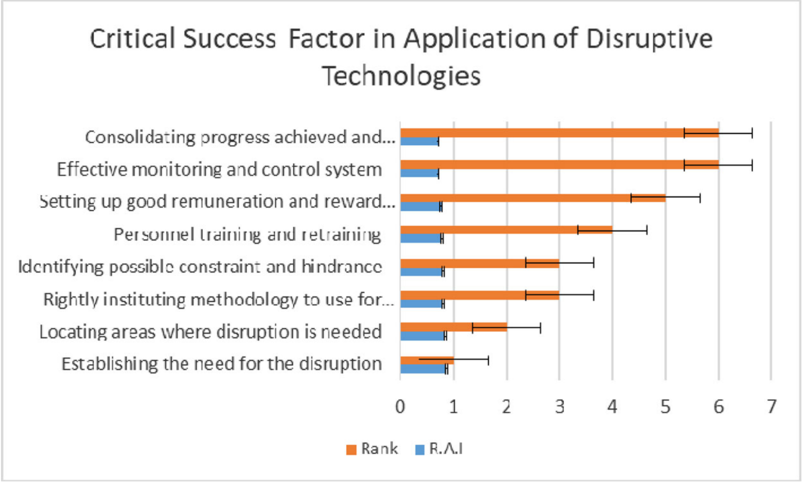

Figure 3. Critical success factor in application of disruptive technologies chart with error bars.

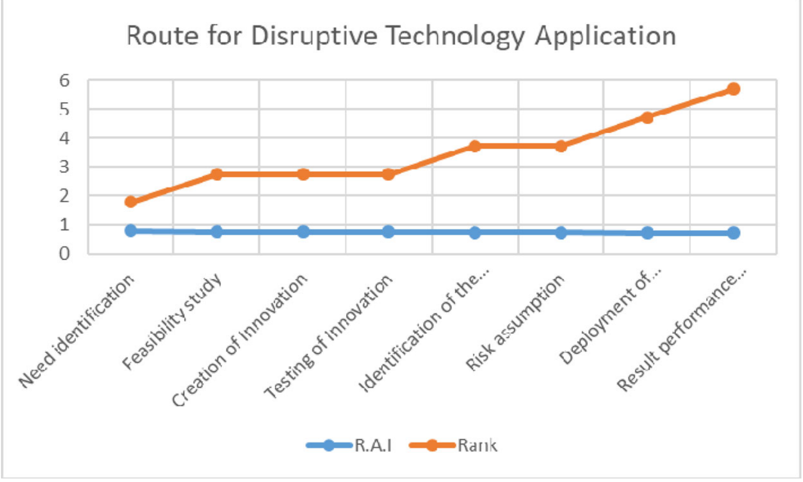

Figure 4. Proposed route for deployment of disruptive application in sustainable construction.

carry out feasibility study which was ranked 2nd, Creation of innovation after need identification also was ranked 2nd, as well as pilot test of the innovation (also ranked 2nd). Similarly, risk involved in the application of the disruptive application need to be established and risk assumption were ranked 3rd while deployment of innovation and result performance validation were ranked 4th and 5th, respectively. Hughes et al. (2019), Evans-Greenwood et al. (2019) and Vertakova et al. (2016) emphasize on effect of sudden innovations on company, the effect could lead to company and organizations falling from height of success and achievement. In order to have an inclusive innovative approach to achieving sustainable construction an holistic approach need to be integrated into procedure to adopt, for instance, stakeholder inclusion, contributory innovative approach, integrating Internal work environment and external work environment and effective integration of steps. In addition to Hughes et al. (2019), Evans-Greenwood et al. (2019) and Vertakova et al. (2016), also, Saki (2016), IITA (2015) and Kodama (1992) supported the view about the fact that internal and external stakeholder management and project environment synergy is very crucial to deployment of innovation for an inclusive project innovation. Internal and external collaboration in term of idea sharing and processing is one of the cardinal requirements as well for fulfilment of effective project innovation.

Achieving millennium development goal through disruptive innovations and fourth industrial revolution

Millennium development goal thirteen (13) borders about innovation, technological advancement, knowledge acquisition and technology development and transfer. However, the SDG goal could be achieved within the ambit of technological innovation. Industrial revolution comes along with all components that can facilitate technological innovation. Therefore, in this section strategy that could be used to achieve SDG goal 9 using disruptive innovations was profiled and presented in Table 5. The parameters stated above can be summarized as technological infusion and development paradigm. Innovation is essential at all facets of technology and infrastructural development, therefore framework and paradigms are needed for successful delivery. Integrating automation in production process could be accessed for effective delivery, for instance four groups of parameters can support integration of automation in construction production technology infusion, and it includes: innovation invention, infrastructural development, scientific research, technology transfer and monitoring and control system among others. This view was supported in Martino and David (2000) IITA (2015) and Kodama (1992), the studies summarily stated strategy to support technology infusion, development and integration.

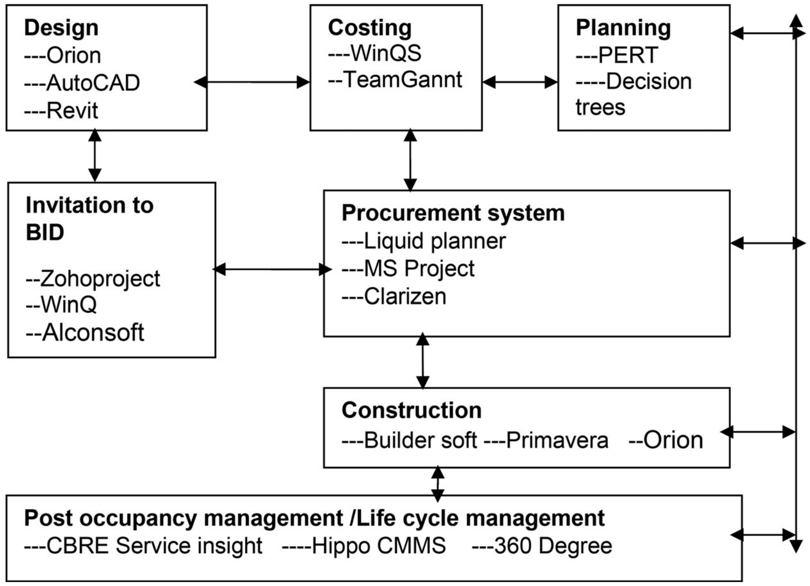

Figure 5. Developed model of drivers of disruptive innovations in construction industry.

Model of major drivers of disruptive innovations in construction industry and their functionalities

A Hierarchical framework was developed and presented as shown in Figure 5, it represent combinations of disruptive innovation drivers that enable technological disruption in construction sector. The framework presented in Figure 2 showing their interdependencies. Design, planning and costing are tripartite variables in the foundation of the hierarchical system. Planning cut across all facet of disruptive cycle. In Figure 5, in Design, some applications that could be used in design include Orion, AutoCAD and Revit. Revit helps in rendering design for construction work. The application has added impetus to the delivery speed in building design. Also, applications such as Zoho-project, WinQ and Alconsoft assist in fast tracking procedures during invitation to bid process. In Costing, WinQS and Team Gantt has change game speed in helping spreadsheet and taking off procedures and developing cost implication of building design. Similarly, in Planning of building and construction process, MS project, PERT, Decision tree has been useful in planning and scheduling of project resources. Similarly, in construction, Builder soft, Primavera and Orion are disruptive technologies aids production of building documents, planning of resources, Orion help in structural detailing of building works among others. Finally, disruptive technology in post occupancy management and life cycle management include CBRE service insight, Hippo CMMS and 360° degree (Kodama 1992; IITA 2015).

Discussion

In this section the detail of how the outcome of this research can be used in practice is presented within the scope of the following parameters: Economic and commercial impact, the influence of the research to policy makers and contribution to body of research knowledge.

a. Economic and Commercial impact.

This study has brought to the fore some tools that has the key to major disruption in construction industry which should further be harnessed, majority are BIM and Block chain technology related, BIM has potential of increasing productivity when adopted rapidly in the value chain to encourage sustainable growth and can aid delivery of cost effective services, operations efficiency and improved infrastructure. Therefore, application of BIM and Block chain technology which forms a nucleus of disruptive technology has potential to transform economy and enhance profitability in commercial ventures. The opinion above was corroborated by the works of Pardoe et al. (2018), Wank et al. (2016), Garnsey and Hang (2011) and Fillipov and Mooi (2019), highlighting importance of digitalization in economic development.

Similarly, one of the areas that the impact of this study could be felt is in improvement of operations and processes. The study has demonstrated areas that disruptions have taken place and the gains accrued from there. The study has laid emphasis to innovation as a means of change and that Innovation is the vehicle of economic development and the more reason for the proliferation of digital technology which has led to disruption in several aspect of nation's economy especially the construction industry. Technological disruption has proven to be the major key in the achievement of SDG goal 9. However, this toes the line of submission presented in (Vertakova et al. 2016; Evans-Greenwood et al. 2019). Disruption innovations have tendency to increase the per capital income of construction companies and change faces of manufacturing and production management in construction industry. This study has brought to the fore the tools that has the key

a. Impact on enacting Effective Public Policy

In the context of this study, certain components of the findings are proected.

Howbeit, formulating policy around dynamics of internal and external project environment, stakeholder management and innovation procurement route are some of the important areas that could help maximize the gains of innovation right from idea conception stage to deployment of innovations as presented in this study. Therefore, this was supported in Huang et al. (2004) that suggested four parameters to achieving innovations, the strategic management, stakeholder management, internal innovative work environment and external work environment (Sindhu Vaardini and Shanmugapriya 2018).

Moreover, some literary presentations supported the opinion presented above if incorporated into policy formulation, that could lead to disruption in the built environment, for instance, Hughes et al. (2019), Jiao et al. (2019) and Noor (2009) submitted that there are different types of planning that could be used, e.g. short term planning, medium term planning and long term planning that could lead to technological disruption. With reference to the survey, major area of disruption is in planning of construction works. The truth lies in the fact that there are many innovations and packages that could be used in planning construction works at feasibility and planning stages as stated earlier in the body of this work, for instance Programme Evaluation Review Technique (PERT) and related software are being used at planning stage to prepare feasibility study, time and cost projection, creation of master programme and general construction resources planning and programme among others. Furthermore, uncertainty in the performance and selection of innovative systems is often leveraged on certain extreme ideals which tend to classify technology to be used into classes, for instance, technology to be adopted can be classify into high tech, low tech and medium tech innovations, this submission is corroborated by a study carried out by Hughes et al. (2019), Noor (2009), Vertakova et al. (2016), Amusan et al. (2019a), Yamazaki and Maeda (1998) and Angus and Stockling (2017), which in their submissions affirmed that in every economic scenario, project are often classified into various degree depending on project level of complexity, also that projects can be categorized into four dichotomies, i.e. low tech project, medium tech project, high tech projects and super high projects. Technicality involve in a project would determine the level of innovations required or fulfilment of its delivery.

Furthermore, there are lot of benefits derivable from industrial 4.0 application in creating a sustainable development and technological infrastructures as pointed out in this study, the benefits were summarized in Blayse and Manley (2004) and Oesterreich and Teuteberg (2016), some of this include (a) symmetrical and asymmetrical parallelism of technological innovation, people and environment, (b) precision and accuracy in production and manufacturing, (c) effective synchronization of work, process and environmental for sustainable development.

Finally (Kodama 1992; Martino and David 2000; Garnsey and Hang 2011; IITA 2015; Fillipov and Mooi 2019), in their study posited that strategy to support technology infusion, development and integration. Technological infusion, development and integration could be achieved through policy formulation around certain parameters like integrated design, sketch design, process planning and control, building system optimization, project simulation, site automation system, project management system and factory production system. The mentioned factors are adjudged to have potential of leading the way to successful achievement of sustainable industrial goal 9 as contained in the objectives earlier stated. On this note therefore, the following policy recommendations would help in the effective disruptive intervention towards achieving millennium development goal 9: Investing in the innovation in the industry, Encouraging infrastructural development, Bridging the technological and digital divide in construction sector among others.

Usefulness of the research (contributing to the body of knowledge)

Also, issues that borders about, internal and external project environment, stakeholder management and innovating and management of innovation procurement route are some of the important areas that the outcome of this research work could be beneficial. It would help to maximize the gains of innovation right from idea conception stage to deployment of innovations, they are line of thoughts presented in this study that are germane and could serve as watershed in the study of procurement route for causing disruption in the technological context of the society (Vertakova et al. 2016; Deloitte 2019; Fillipov and Mooi 2019).

Also, industry4.0 through deployment of technological innovations that comes with it hold key to accessing technological disruption which could assist in delivering sustainable goal 9 as demonstrated in this study therefore focussing on research work in industrial development could help in achieving all the sustainable goals.

Finally, a philosophical point was presented in the study on account of strategies to the fulfilment of sustainable development goal by 2030, that status-quo-ante mentality should be abolished taking symmetrical and asymmetrical attitudinal disposition approach to technological innovation, invention and knowledge transfer responsibility (Yamazaki 2003; Kavanagh and Naughton 2009) In other words, research work could be carried out on vertical integration of disruptive innovations by considering product synchronization and development. This study would serve as a watershed in the study of technological disruption in industry 4.0 in the achievement of United Nations Sustainable Development Goals particularly as regards means to achieving sustainable development goal study globally (Angus and Stockling 2017; Rouse 2017).

Disclosure statement

No potential conflict of interest was reported by the authors.

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