Appraising fourth industrial revolution technologies role in the construction sector: how prepared is the construction consultants?

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Abstract

Purpose – In the past, the construction sector faced a low technological development level. Recently, studies have shown that the fourth industrial revolution (4IR) technologies play a significant role in construction project performance. But how prepared are the developing countries' construction consultants, a focus in Nigeria, in embracing the 4IR technologies in construction administration is yet to receive in-depth research. Thus, this paper aims to examine how Nigerian construction consultants are prepared to embrace 4IR technologies in pre- and post-construction activities.

Design/methodology/approach – To evaluate the perceptions of construction consultants, the study conducted a virtual interview. The participants were asked the following key questions: What technologies that are currently linked with the 4IR and used by construction consultants in the industry? What factors may hinder the strategic application of 4IR by the construction consultants? What initiatives may be necessary to overcome the perceived encumbrances faced by the construction consultants? Twelve semi-structured

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interviews from selected construction consultants were engaged and collated data analysed via a thematic approach.

Findings – The paper identifies digital software used by construction consultants that have a link with 4IR technologies. From the ten emerged hindrances, cost of adopting the technologies, unwillingness on the part of stakeholders to adopt, inadequate standards and reference architectures and absence of awareness were ranked high as the factors hindering construction consultants from using 4IR technologies. Initiatives that can overcome the perceived encumbrances are examined in detail.

Research limitations/implications – This study is restricted to construction consultants in Nigeria, and only 12 participants were engaged, but these do not affect the strength of the results. Thus, this study recommends a mixed-methods approach for future research with broader coverage.

Practical implications – The Government should intervene via subsidy regime and overhaul the academic curriculum to reflect the current trend of practices regarding technologies. Also, there should be vigorous enlightenment and pragmatic sensitisation of construction stakeholders and knowledge training of practitioners, among others, were suggested. As part of this paper's implications, a perception-based model was developed to promote 4IR technologies for construction consultants in the Nigerian construction sector. This model encourages the construction consultants to embrace 4IR technologies for better service delivery, project performance and client satisfaction.

Originality/value – This paper appraised 4IR technologies' role in the construction sector, focusing on the preparedness of the construction consultants in Nigeria. Also, the study identified the issues and proffer initiatives to improve 4IR usage by construction consultants.

Keywords Nigeria, Construction industry, Qualitative techniques, Construction experts, Technological revolution

Paper type Research paper

1. Introduction

Improving the construction sectors of the developing nations has become a paramount demand because of the emerging economies from these countries. In many developing countries, the construction sector is one of the main sectors and offers the infrastructure for economic advancement (Ebekozien, 2020; Osunsanmi *et al.*, 2020). The construction industry can be described as one unique industry that allows for the pre-construction (planning and design), construction (development) and post-construction (modification, maintenance and final demolition of buildings) of works. This cycle enhances economic and social activities. Weber and Alfen (2016) opined that the construction sector is a component of our lives because it creates economic wealth, maintains the society's well-being and organisational backbone of an economy. The construction sector is faced with inadequate knowledge in advanced technologies yet worth over $10tn per annum (Bogue, 2018). The design team (construction consultants), contractors and clients (employers) are the key participants in the construction industry (Ebekozien, 2020). For this paper, the focus is on construction consultants. The construction consultants are major stakeholders in the built environment sector. They may be slow to use innovative digital technologies, such as three-dimensional (3D) printing (3DP), cyber-physical systems, blockchain, digital twin, augmented reality, robots, big data, among others. These innovative digital technologies belong to the 4th industrial revolution (4IR) (Hooker and Kim, 2019; Alade and Windapo, 2020; Osunsanmi *et al.*, 2020; Ebekozien and Aigbavboa, 2021). The technology is enabled by using advanced technologies such as 3DP into the production (Tjahjono *et al.*, 2017; Hirschi, 2018; Trauth-Goik, 2021). In developing countries, the sector is lagging in digital technology usage (Aghimien *et al.*, 2020). Thus, integrating these technologies into construction consultants' operations cannot be over-emphasised because of their potential significance. Goulding *et al.* (2015) and Shakor *et al.* (2020) identified a decrease in waste from accurate material placement, enhanced skills for bigger customisation of designs and parameters for

functional and aesthetic uses and promoted the use of recycled waste materials as some of the benefits of the 4IR technologies. The use of blockchain, robots and 3DP has increased (Lemieux and Lemieux, 2016).

The role of 4IR in construction activities, especially for construction consultants, has become germane because world technology is evolving (Aghimien *et al.*, 2020). Against this backdrop, an investigation of the factors that hinder the strategic application of the 4IR technologies and the initiatives that may be necessary to overwhelm the perceived encumbrances faced by the design team within the Nigerian context is pertinent for some reasons. First, despite Nigeria's construction sector growth, the country's construction consultant exposure to advanced technologies in advancing their service delivery is still weak. Some stakeholders are looking for ways to strengthen their technological capability and 4IR leadership (Alade and Windapo, 2020). Second, Nigeria being one of the fast-growing emerging economies and the giant of Africa needs advanced technology in construction to meet the demands of infrastructural facilities. Thus, stakeholders are looking to leverage the technology to enhance the technological capability of the major player (construction consultants) in the sector. Possible issues are facing technological advancement in the construction sector. Third, to respond appropriately to these encumbrances, stakeholders should know the critical variables that hinder the strategic application of 4IR technologies and the initiatives that may be necessary to overcome the perceived encumbrances faced by the construction consultants. How far Nigerian construction consultants are in the issues and feasible solutions to improve the application of 4IR in the industry is yet to investigate in-depth. Few studies in this area, for example, Ayentimi and Burgess (2019) and Alaloul *et al.* (2020), did not address their studies from the construction consultants' perspective, that is, the factors that hinder the strategic application of 4IR technologies. Ayentimi and Burgess (2019) examined the benefits and limitations of the 4IR to emerging economies in sub-Sahara Africa and derived their findings from secondary sources. Alaloul *et al.* (2020) focused on the challenges and opportunities for the stakeholders, including the construction consultants, in engaging 4IR technologies in the built environment. Thus, this paper attempts to offer a collective insight into many underlying issues affecting construction consultants regarding the poor strategic application of 4IR technologies and proffer feasible solutions. This study aim will be accomplished via the following stated objectives:

- to examine the technologies currently linked with the 4IR and used by construction consultants in the industry;
- to investigate the issues that may hinder the construction consultants' strategic application of 4IR technologies; and
- to examine the initiatives necessary to overcome the perceived encumbrances the construction consultants face.

2. Overview of the role of construction consultants in developing countries: a case study of Nigeria

The anti-poverty war, high infant mortality, illiteracy, low-life expectation and other low levels of socio-economic growth manifests in many developing countries. Leaders across the globe are trying to mitigate these challenges that are threatening human existence. At the international level, the world leaders have agreed on the 17 points Sustainable Development Goals on or before 2030. Scholars such as Ebekozien *et al.* (2021) stated that this can be achieved via the construction sector. Scholars in the construction sector are responsible for

contributing to the effort to mitigate these life-threatening factors, such as abject poverty, especially in developing nations. First, infrastructure and production facilities are provided via the construction industry. This makes a remarkable contribution to national socio-economic growth (Ofori, 2007). Second, a larger portion of the national economy is derived from the sector (Hillebrandt, 2006; Ofori, 2007). Third, the construction sector is a good platform for entrepreneurship and technology transfer (Ofori, 2007). The latter is one of the areas that the focus of this paper will be addressing, emphasising construction consultants. The three key and common construction consultants in building projects are Architect, Quantity Surveyor and Engineer (Ramus *et al.*, 2006). They are professional advisers to the client/employer. They are responsible for the conceptual design, drawings, specifications, instructions, contract documentation, supervision, delivering the construction project within cost and time and the design and quality performance (Ashworth, 2010). The construction consultants or design team is a much bigger project team component.

In Nigeria, the Architect is well trained with the skill and knowledge to enable them to originate the design and plan, without detailed brief from the client. In some cases, arrange for and supervise the erection of the building projects or other works. The Structural Engineer is responsible for the design and detailing of the structural drawings, while the Services Engineers are responsible for the design and supervision during construction (Onwusonye, 2005; Ebekozien *et al.*, 2013). The Quantity Surveyor (QS) is the leading expert in construction cost estimating and measurement, legal formulation, packaging and the interpretation of the legal aspect of the contract, including the contractual rights, duties and obligations of respective members of the team. Also, the QS specifically provides cost advice and information before the contract is awarded to a specific contractor and values work during the progress of the construction (Ebekozien *et al.*, 2013). In this 21st century, these construction professionals need advanced technologies to enhance their performance and service delivery to their clients. The importance of advanced 4IR technologies software in the sector has grown exponentially over the past decade (Osunsanmi *et al.*, 2020). The authors affirmed that with the development in construction design and skill, the scope of construction activity has changed in scale, complexity and diversity.

3. Fourth industrial revolution technologies' role in the construction sector

From the first industrial revolution in the early 1700 s to today's 4IR that started about one decade ago, technology and people connectivity have increased with better performance. The 4IR messengers to transform lives for better-unprecedented changes to the world's economic, social and cultural fabric (Schwab, 2017; Hooker and Kim, 2019). This industrial revolution is the main component of Science Technology Engineering and Mathematics (STEM) via the attributes of speedy innovations such as biotechnology, artificial intelligence, advanced robotics, digitalisation and automation (Park, 2018). Papadopoulou (2020) affirmed that the fourth industrial revolution (4IR) would enlarge the request for the expertise and challenge the STEM pipeline by redefining the labour market. The construction consultants belong to this group. STEM Learning (2018) projected that about 89% of businesses face challenges employing professionals and forecasts that fresh responsibilities in STEM may double in the subsequent years. Oesterreich and Teuteberg (2016) identified 4IR technologies into three clusters. The first cluster (smart factory) includes modularisation, robotics, cyber-physical systems, human–computer interaction, automation, radio-frequency identification and Internet of things/Internet of services. The second cluster (simulation and modelling) includes building information modelling, simulation tools/models and augmented reality/virtual reality/mixed reality. The third cluster (digitisation and virtualisation) includes cloud computing, social media, big data and

mobile computing. Globally, there is a call to promote investment in 4IR expertise to mitigate the technological shock waves in the 21st century (World Economic Forum, 2018; Trauth-Goik, 2021).

The construction sector has the unique potential to power the 4IR technologies. This includes providing smart homes to address the housing shortage and delivering critical transport infrastructure (World Economic Forum, 2016; Hawksworth *et al.*, 2018). The acceptance and application of the 4IR technologies have not been encouraging among the practitioners, including the construction consultants or design team, especially in developing countries. Against this backdrop, an investigation of the variables that hinder the application of the 4IR technologies and the initiatives that may be necessary to overcome the perceived encumbrances faced by the design team within the Nigerian context is pertinent, as previously highlighted. This is the key premise of this study, investigating the issues that hinder the strategic application of 4IR technologies and examining the initiatives that may be necessary to overcome the perceived encumbrances faced by the construction consultants. Table 1 summarises selected related studies within African developing countries (Alade and Windapo, 2020; Aghimien *et al.*, 2020) and others (Oesterreich and Teuteberg, 2016; Bogue, 2018; Ayentimi and Burgess, 2019; Alaloul *et al.*, 2020; Kim *et al.*, 2020; Nkosi *et al.*, 2020; Osunsanmi *et al.*, 2020; Tahmasebinia *et al.*, 2020).

4. Research method

Studies are gaining new information on the basic phenomena and realities via the theoretical study (Stysko-Kunkowska, 2014; Denzin and Lincoln, 2017; Creswell and Creswell, 2018). A qualitative research methodology was adopted because of the new and unexplored nature of the study issue (underlying issues affecting construction consultants regarding the poor strategic application of 4IR and proffer feasible solutions). This approach offers an opportunity to deal with work contexts (Garcia and Gluesing, 2013). Primary data were collected from 12 semi-structured virtual interviews from selected 12 construction consultant firms and collated data analysed via thematic approach as presented in Table 2 from Lagos and Abuja. Both locations are commercial hubs in Nigeria with large construction activities. Gruber *et al.* (2008) and Jallow *et al.* (2020) affirmed that semi-structured interviews offer flexibility to obtain a realistic perspective of the participants' opinions. As presented in Appendix, the semi-structured interview questions helped in answering this paper's research questions. They are:

RQ1. What technologies are currently linked with the 4IR and used by construction consultants in the industry?

RQ2. What factors may hinder the strategic application of 4IR technologies by the construction consultants?

RQ3. What initiatives may be necessary to overcome the perceived encumbrances faced by the construction consultants?

For this paper, purposive and snowball sampling techniques were adopted to achieve participants' representativeness (Teddlie and Tashakkori, 2010). The purposeful sampling selected the major participants. Snowball sampling involves drawing reachable and prepared samples to contribute to the research (Saunders *et al.*, 2019). The study sample included selected Architects, Quantity Surveyors and Engineers in private consultant firms with vast knowledge concerning ICT and 4IR technologies in the construction sector. The virtual interviews via video conferencing lasted between 45 and 60 min in each interview. Before the

Author (s)	Method	Main aim	Main findings
Alade and Windapo (2020)	Quantitative method	The study examined the relationships between leadership styles and 4IR in South African construction firms	Findings show that effective leadership is needed to spread the knowledge of 4IR opportunities and threats in the companies. Employees should be encouraged to acquire 4IR skills
Aghimien *et al.* (2020)	Mixed methods	The paper evaluated critical factors needed for successful digital partnering of construction firms	Trust in digital partners, top management support and partner selection were identified as the three major success factors for partnering
Oesterreich and Teuteberg (2016)	Combination of review and case study	The study examined the state of practice of Industry 4.0 technologies in the construction industry	The state of the art of these technologies is on different maturity levels. Also, digitalisation and automation of the construction will improve productivity, quality and collaboration
Bogue (2018)	Case study	The study focused on the current uses and possible future role of robots in the built environment sector	The study discovered that many robots are at a progressive development phase while few in use seek to automate conventional building practices
Ayentimi and Burgess (2019)	Review	The study focused on the prospects and challenges of the 4IR in emerging economies in sub-Sahara Africa	The large informal economy, inadequate public infrastructure, skill shortages in key sectors including the construction sector, insufficient experts except in multinational companies staffed by foreign staff, absence of policy development, among others, have been identified as the hindrances facing the use of 4IR in the Sub-Sahara Africa's construction sector
Alaloul *et al.* (2020)	Quantitative method	The study identified the issues delaying the implementation of IR 4.0-related technologies within the built environment sector	Technical and social factors emerged as the contributing factors influencing the implementation. The major stakeholders were involved in the study and concluded that IR 4.0 within the industry is still lacking
Kim *et al.* (2020)	Quantitative method	The study investigated the approach to use blockchain technology in the construction sector	The study discovered that construction contract bidding, procurement evaluation and construction project cost were the three major areas the blockchain technology can be used with important impact
Nkosi *et al.* (2020)	Review	The study examined 4IR approaches that should be implemented to improve infrastructures in developing countries'	The study found that 4IR technologies are helpful within the university's infrastructure. It can be used to resolve infrastructure challenges within the system

(*continued*)

Table 1.
List of selected related studies and main findings

Author (s)	Method	Main aim	Main findings
		higher institutions emphasising on industrialisation and humanising innovative capacity	
Osunsanmi *et al.* (2020)	Quantitative method	The study evaluated South African construction professionals' willingness to adopt construction 4.0 technologies	There is a low possibility of integrating 4.0 technologies for construction projects. One of the reasons is that construction professionals perceived technologies such as robotics, the Internet of things and human–computer interaction as unimportant
Tahmasebinia *et al.*, 2020	Case study and quantitative	The study evaluated the sustainable performance criteria for three-dimensional printing practices into house construction in the sector's 4IR	The study found maximum tensile stress within a flat roof. Also, there will be few advanced technologies in the future

Table 1.

ID	Consultant firm	Location	Participant rank
P1	Architectural firm	Abuja	Senior Partner
P2	Architectural firm	Abuja	Managing Partner
P3	Architectural firm	Lagos	Chief Senior Resident Architect/Part-time lecturer
P4	Architectural firm	Lagos	Director
P5	Quantity Surveying firm	Abuja	Senior Resident Quantity Surveyor
P6	Quantity Surveying firm	Abuja	Partner
P7	Quantity Surveying firm	Lagos	Chief Executive Officer/Part-time lecturer
P8	Quantity Surveying firm	Lagos	Managing Partner
P9	Structural Engineering firm	Abuja	Chief Senior Resident Engineer (Structural Design)
P10	Services Engineering firm	Abuja	Chief Engineer (Coordinator)
P11	Structural Engineering firm	Lagos	Managing Partner
P12	Services Engineering firm	Lagos	Director

Table 2. Summary of participants' description

main interview, a pilot study was conducted with two participants and the questions were slightly reversed. The collated data were analysed using thematic analysis, according to Ebekozien's (2020). The author adopted a thematic approach in similar qualitative studies. Between early November 2020 and late December 2020, 12 interviews took place and saturation was achieved. The interviewees' consultant firms were concealed but considered knowledgeable in ICT and 4IR usage in the construction sector. For example, Participants *P2*, *P7* and *P10* have over 20 years of work experience in construction-related information technology in practice. To strengthen the credibility and reliability of the qualitative data, the researchers adopted a quality assessment strategy. It is in line with Wearing (2013, p.98) and Yin (2014, p. 34), as presented in Table 3. Plano-Clark and Creswell (2015) emphasised that

credibility in qualitative research depends on the researcher's effort as the instrument. Words such as credibility, transferability, reliability, validity and generalisability were adopted as presented in Table 3.

The participants were informed about the study's main aim and accepted to participate without coercion concerning ethical issues. This research follows the global best practices regarding research ethics and the interviewees presented in an anonymous form. Open coding of meaning units in the transcribed virtual interviews data was adopted. Invivo, emotion, narrative and themeing coding techniques were used (Corbin and Strauss, 2015). One hundred and forty-four codes were generated and re-organised based on occurrence, reference and frequency. Ten categories were derived from the 144 codes and three themes (technologies linked with 4IR and used by construction consultants, issues affecting 4IR technologies usage and possible solutions to mitigate the hindrances) emerged. The study engaged an independent expert to cross-check the themes. Also, fears of findings validity were alleviated via triangulation of data collection mechanism (Tajeddini and Mueller, 2009).

5. Results and discussion

Issues affecting developing countries' construction consultants' low level of technology usage in connection with the 4IR technologies, a case study of Nigeria, is one area that has been under-researched by scholars. It may have interrupted service delivery and performance of the design team to their clients. The relevance of 4IR technologies cannot be over-emphasised because the emerging technologies work as end-to-end advanced and digitalised technology in engineering across the value chain. Therefore, findings and discussion are presented below:

5.1 Theme one: technologies used by construction consultants and linked with Fourth Industrial Revolution

This sub-section identifies common technologies currently linked with the 4IR technologies and used by the design team. This paper adopted Oesterreich and Teuteberg (2016) clusters' classification (smart factory, simulation and modelling and digitisation and virtualisation), where key technologies are linked with the 4IR. One of the pertinent opinions that emerge is that engaged construction professions (Architects, Quantity Surveyors and Engineers) agree that building information modelling, Internet, big data, mobile computing, social media and digitisation are the common

Table 3. Representation of the study's quality assessment strategies

Method	Assessment strategies	The phase of research
Reliability	Consistent interviewer (The lead author)	Data collection
Validity	The adoption of a recognised approach (semi-structured virtual interviews	Data collection
		Data collection
Generalisability	Recognition of limitation due to sample size potential interviewer bias (Focus on experts)	Data analysis
Transferability	Compare study's implications against current literature	Post data analysis
Credibility	Theme approach to establish a pattern from the data	Data analysis
	Explanation building in sequential order, objective by objective	Data analysis
	Address rival explanations, e.g. The nepotism issue raised by *P5*	Data analysis
Dependability	Developing semi-structured interview guidelines (Appendix)	Research design

Source: Modified from Wearing (2013, p. 98) and Yin (2014, p. 34)

technologies used. They have a link with the 4IR technologies. Examples of the BIM software are Revit Architecture and ArchiCAD for Architects (Participants *P1*, *P2* and *P4*), Revit Structure and Digital Project for Engineers (Participant *P9, P11* and *P12*) and Revit, Vico Office and CostX for Quantity Surveyors (Participants *P6* and *P8*). Participant *P11* says, "[. . .] *Revit for Quantity Surveyor is a unique BIM software. The software assists to extract data from the 3 D digital models designed by the Architect and automatically generates schedules for doors, windows and other materials [. . .]. Similar functions as CostX and CostX Takeoff software but expensive to procure* [. . .]" "[. . .] *Revit Architecture is a BIM-orientated digital design tool with smart object connectivity and allows coordination of other key stakeholders collaborating on the same project* [. . .]" said Participant *P1*. Findings agree with Oesterreich and Teuteberg (2016) and classified simulation tools/models, BIM and augmented reality (AR) as components of 4IR technologies. Software associated with BIM productivity belongs to the category of simulation and modelling. Simulation and modelling belong to the 4IR technologies group components identified and classified by Oesterreich and Teuteberg (2016). The software expedites the delivery and optimisation of a construction project.

Majority of the participants agree that with globalisation and current trend, developing countries' construction consultancy firms cannot survive international services engagement without internet facilities. "[. . .] *internet of services allows the formation of computer-generated networks to support smart construction consultant firms that design smart buildings in the 21st century and are more beneficial to digital and smart building developers* [. . .]" said Participant *P12*. This technological concept in the content of 4IR belongs to the smart factory group. Participants *P3* and *P7* identify Blockchain technology as a platform for implementing Big Data solutions and digitalise building data. This mechanism will make these data accessible to project participants. Also, it will allow for an evaluation of construction risks for performance developments in future construction projects. This is germane for productivity and better service delivery from the construction consultants to the industry's clients/employers and other stakeholders. Mobile computing is one of the major technologies the design team uses as agreed by the participants across the board and has a link with the 4IR technologies. Findings agree with Welsh (2015) and found that the majority of the construction professionals use smartphones and tablets for work purposes, as reported in Construction Technology Report in 2015. Social media usage cannot be over-emphasised regarding 4IR technologies. This is one platform that the construction consultants have explored for project management and client networking. Participant *P5* says, "[. . .] *this platform offers me the privilege to engage other members of the team to sight, share, mark and synchronise digital drawings on their tablets and in the cloud, respectively* [. . .]" This makes conversation easier between onsite and off-site project teams. But, this medium has not been well used. Also, micro Team meetings, Zoom and video meetings are key technologies of the 4IR components of digitisation and virtualisation, used by the design team to enhance their productivity. The digitisation of construction consultant firms will transform the sector's image (Participants *P7, P9* and *P11*). Participant *P6* viewpoint says, "[. . .]*Many construction consultants are yet to wake-up from their conventional approach taught two or three decades ago [. . .] We are in the era of smart buildings with an emphasis on smart meters, smart sensors and smart materials in the building environment with advanced technologies that reunite human control and mechanisation [. . .]"* This is one of the main challenges. Majority of the participants know how this software operates and its benefits, but they are not using them because of some issues that this paper attempts to address in the next section.

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5.2 Theme two: issues affecting Fourth Industrial Revolution technologies usage

A few literature regarding the factors that may hinder the strategic application of 4IR in the construction sector exists but none from the perspective of Nigerian construction consultants. The reviewed literature shows that diverse encumbrances face the construction consultants as the first set of professionals to initiate the 4IR mechanism and possibly suggest some 4IR technologies to the construction team via the design and contract documentation. Thus, this sub-section provides the interviewees a platform to identify the issues affecting 4IR technologies usage by Nigerian construction consultants. Findings show that the developing countries' construction consultants are far behind in designing and constructing smart buildings because of some issues. Ten issues emerged from the field data as the factors hindering construction consultants from using 4IR technologies. This includes:

- lack of awareness;
- construction projects complexity;
- cost of adopting the technologies and use;
- unwillingness on the part of stakeholders to adopt;
- projects uncertainty;
- data security and data protection;
- services rendered that hinder long-term thinking and support short-term thinking;
- design team strong resistance to change;
- inadequate 4IR technologies knowledge; and
- lack of standards and reference architectures.

From the ten emerging hindrances, cost of adopting the technologies and use, the unwillingness of stakeholders to adopt, absence of standards and reference architectures and inadequate awareness were frequent among the participants as the factors hindering construction consultants from using 4IR technologies. Participant *P5* says, "[. . .] *we attempted to procure Vico Office* via *a connection from the United States of America-based senior colleague, but the software cost, installation and training charge discouraged us. How many quantity surveying consultancy services can we engage to recover the costs? A country where jobs are awarded to 'know me, I know you,' with high nepotism and mediocrity sponsored and encouraged by some persons.*" The participant rebuffed a followed-up question to elaborate on the nepotism issue. This is coupled with inadequate infrastructure across many developing countries, including Nigeria (Participant *P3*). Findings agree with Manda and Dhaou (2019) and found that many developing countries are being faced with infrastructure and technological hindrances (poor ICT infrastructure). These advanced technologies need enabling environments such as stable electricity supply, digital connectivity and advanced digitalised technology to perform.

Majority of the participants agree that professional Institutes (such as the Nigerian Institute of Architects, Nigerian Institute of Quantity Surveyors, Nigerian Society of Engineers), statutory regulatory bodies (such as Architects Registration Council of Nigeria, Quantity Surveyors Registration Board of Nigeria and Council of Registered Engineers of Nigeria), and the government have not done enough regarding awareness and benefits of 4IR technologies to stakeholders in the construction industry. Majority of the engaged participants and their colleagues use Civil 2 D, AutoCAD, Coral draw, Excel, Microsoft Project and Masterbill for their daily operation. One of the possible

reasons is the fear of job loss and being replaced by machines and computers. Lack of awareness of the benefits has been attributed. Regarding inadequate 4IR technologies knowledge and lack of standards and reference architectures being ranked high among the hindrances, Participant *P3* says, "[. . .] *The built environment and engineering curriculum in many developing countries, including Nigeria, is obsolete. These professions (architecture, quantity surveying and engineering) ought to be dynamic, with the primary motive of the scientific study of human interaction with advanced technologies and construction of intelligent buildings* [. . .]" The built environment consultants should be prepared to face reality because the future of the urban built environment relies on smart cities. This requires more functionality with increasingly populated conurbations, scarce resources and severe building regulations. Viewpoints from Participant *P11* says, "[. . .]*we do not have the capacity at present for advanced level of design and construction of structures that can control its building operations and minimise human interaction because there is no standard and strict regulations to guide [. . .] Very few construction consultancy firms with international collaboration or partnership can claim such height of vision* [. . .]" As the globe is within us, the developing countries' construction consultants cannot be exempted from the current trend of happenings. Thus, "[. . .] *4IR technologies knowledge and applicability are inevitable if we want to remain relevant. Presently, homes and other structures are designed for functionality, safety and comfort. The combination of these variables in design is made possible* via *the advanced design software (Civil 3D and CATIA), components of the 4IR technologies* [. . .]", said Participant *P12*. Majority of the engaged participants are willing to key into the 4IR technologies because of the benefits but the encumbrances are beyond their control. The following section attempted to proffer possible solutions and developed a proposed perception-based model to promote 4IR technologies for key consultants in the construction industry.

5.3 Theme three: possible solutions to mitigate hindrances faced by construction consultants

This sub-section examines feasible initiatives that may be necessary to overcome the perceived encumbrances faced in the usage of common technologies that are currently linked with 4IR and used by the Nigerian design team in the construction industry. This has become necessary because studies such as Welsh (2015), Oesterreich and Teuteberg (2016) and Manda and Dhaou (2019) shown that 4IR technologies in design and construction can improve user comfort and satisfaction, encourage green construction and sustainability into the future, resource efficiency, increase quality assurance, mitigate construction cost over-run and time, enhance safety construction and an energy reduction of buildings. Theme three grouped the thirteen feasible solutions to mitigate the encumbrances faced by construction consultants from the analysed data to three aspects (government, organisational and technical aspects). The sub-themes/aspects as presented in Figure 1 were used to develop a proposed perception-based model to promote 4IR technologies for Nigerian construction consultants. This paper attempts to proffer feasible solutions to construction consultants' issues, but the emphasis was on the major issues with high occurrence across the participants. Findings show that the government should intervene in mitigating the high cost of software, installation and training schemes for the users. Participants *P2*, *P5*, *P10* and *P12* recommend a subsidy regime by the government and other corporate institutions such as professional bodies to mitigate the high cost of software and provide funds/grants for programmes tailored towards 4IR technologies research. This may reduce installation and training charges in the future. Findings agree with Smith (2014) and recommended a functional collaboration between the construction stakeholders

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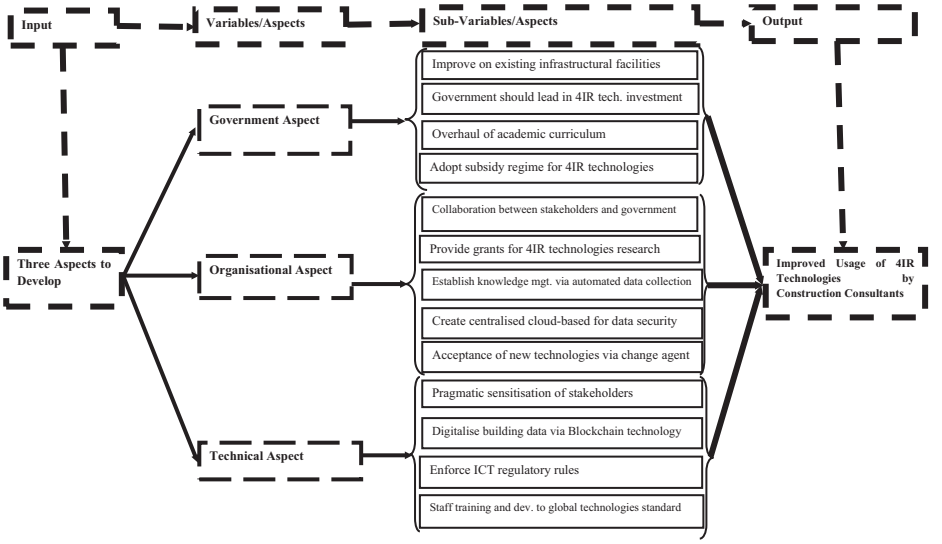

Figure 1.
A perception-based model to promote 4IR technologies for key consultants

professional bodies and the government. Participant *P2* avows that some advanced nations imposed the application of BIM on construction activities. BIM is one of the applications that promote the use of 4IR technologies and the government in these advanced countries leads in the BIM programme investment. The author found that government leaders have intensely invested in funding programmes, implementation plans and incentives associated with BIM mandates and created the enabling environment in the United States of America, Scandinavian region and the UK construction sectors.

Findings suggest pragmatic sensitisation concerning the benefits of these technologies as previously highlighted and vigorous enlightenment of stakeholders to address the issue of unwillingness to adopt 4IR technologies and absence of awareness. This sensitisation campaign should be all-inclusive. The government and non-government organisations should be engaged to drive this campaign to the "grass-root" construction professionals. "Top-bottom and bottom-top approaches" should be adopted to reach out to the big and small construction consultants and possibly convince them to key into the best global practices for service delivery. "[. . .] *emphasis should be on the benefits of 4IR to the consultants, such as service competitiveness globally, mitigate risks/errors in services to the client, better firm image, among others to the users* [. . .]." said Participant 12. Findings recommend that construction consultants should be encouraged to digitalise building data via Blockchain technology. This will mitigate the issue of data storage and enhance the safety management of data affecting the design team. Participant *P7* says, "[. . .] *the Blockchain technology will digitalise building data and assist in sharing information with third parties [. . .]. This implies that the Blockchain technology may unlock contract information for key stakeholders engaged and the artificial intelligence* via *the Blockchain* [. . .]" Findings agree with Bogue (2014) and Veuger (2018). Bogue (2014) affirmed that the application of artificial intelligence technologies is one of the pertinent thrilling areas of robotic advancement and play a role in machine vision, autonomous navigation, dexterous manipulation and localisation and mapping. Veuger (2018) found that Blockchain enhances innovation, values and flexibility in managing residential buildings.

6. Implications for construction consultants and other stakeholders

In the global developing countries context, the research outputs would enrich the knowledge on the 4IR technologies for the construction sector. In Nigeria's context, this paper fills a significant gap in the body of knowledge. This is possibly the first empirical paper to engage key practicing construction consultants (Architects, Quantity Surveyors and Engineers) regarding 4IR technologies and the encumbrances facing their usage through a qualitative approach. The methodological gap has been filled in this study. The participants have offered their knowledge on the critical issues and proposed possible solutions to mitigate these challenges. The proposed feasible solutions may be adopted by developing countries with similar attributes such as economic, social, cultural, political and ICT issues. As part of this paper's implications, the policies and mechanisms to encourage the usage of 4IR technologies by construction consultants in Nigeria have far-reaching benefits to the practitioners and the industry at large. Apart from the economic advantages of the 4IR technologies to the practitioners, such as global service competitiveness, mitigated cost and time over-run, the better image and working environment enhancement, reliable and increase quality assurance, mitigate risk and enhance safety, among others, the technologies are useful tools that can be used to enhance the attaining of sustainable development goals by 2030 regarding construction-related issues, such as water, housing and health-care facilities and promote green construction and sustainability. The paper intends to stir up appropriate stakeholders concerning underlying matters affecting construction consultants in connection with the usage of 4IR technologies in developing countries, using Nigeria as a case study. The outcome intends to strengthen and offer a rich insight into the mechanisms of the 4IR technologies and contribute towards informing key stakeholders to create an enabling platform for the implementation of 4IR technologies. The emerged suggestions from this study are informative to the key stakeholders and formulated a perspective-based model to promote 4IR technologies for construction consultants in developing nations. Among the main contributions, this is a proposed framework to promote 4IR technologies. This has robust theoretical underpinnings and promotes global technological advanced development. The study argues that construction consultants need to be prepared with flexible technological and leadership skills to handle the fast change brought by global technology. Three aspects (government, organisational and technical) were articulated in the proposed perception-based model to promote 4IR technologies and the outcome is improved usage of 4^{th} industrial revolution technologies by construction consultants.

7. Conclusion

There have been studies on 4IR technologies in the construction sector. Studies on the users and implementation have been silent on construction consultants, who are key stakeholders from pre-development to post-development in the construction sector. The paper shows that the level of usage of the 4IR technologies by construction consultants within the industry is not encouraging despite the benefits of these technologies. These benefits are without some challenges which this paper tries to offer viable answers that emerged from the participants perspective. The possible solutions are categorised into government, organisational and technical aspects. Items associated with each aspect were identified and formulated to develop a proposed perception-based model. This framework intends to promote 4IR technologies for key construction consultants and the processes, by extension, will positively impact multiple platforms in the industry. Implementing the proposed perception-based model to promote 4IR technologies for key construction consultants within the construction industry would drive and enlighten other stakeholders in the industry. This will increase the industry's performance because other stakeholders may key into 4IR

technologies in their daily operations, especially the contracting section of the industry. This is a component of the paper's implications.

Thus, this paper should be considered as an early evaluation because further analyses will be undertaken on possible research problems around the issues facing construction consultants in other developing countries. Therefore, the present study is exploratory. However, some conclusions such as the proposed perception-based framework to promote 4IR technologies can be drawn from this paper to guide policymakers, researchers and construction practitioners in Nigeria and other developing countries with similar attributes. This does not affect the robustness of the study. Although the proposed perception-based framework to promote 4IR technologies emerged from the participants' perspective, it is not without limitations because of the limited number of participants and coverage areas. The paper recommends exploratory sequential mixed methods research design for further research. This method will enhance generalisability in line with Ebekozien *et al.* (2019). The authors recognised that the mixed methods approach aid scholars in verifying and validating the qualitative results. This research gap is possibly missing in past research works regarding construction consultants and the 4IR technologies. Also, the need for future study in other developing countries with similar attributes regarding 4IR technologies usage in the construction sector cannot be over-emphasised. As part of this paper's implications and general relevance, the paper is supporting the transformation of a model to develop a perception-based that will promote 4IR technologies for construction consultants in Nigeria's industry. Also, the proposed framework may improve the level of usage of 4IR technologies by construction consultants in Nigeria if implemented. This paper is envisioned to stir up other stakeholders in the construction sector. Hopefully, new openings for further studies, such as the moderating role of government in driving 4IR technologies, may emerge.

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Appendix

Dear Participant,

Request for Virtual Interview

In the past, the construction sector faced a low technological development level. Recently, studies have shown that the fourth industrial revolution (4IR) technologies play a significant role in construction project performance. But how prepared is the developing countries' construction consultants, a focus in Nigeria, in embracing the 4IR technologies in construction administration is yet to receive in-depth research. Thus, this paper examines how Nigerian construction consultants are prepared to embrace 4IR technologies in pre- and post-construction activities. Therefore, this research is titled: *Appraising Fourth Industrial Revolution Technologies' Role in the Construction Sector: How Prepared are the Construction Consultants?* Specifically, this research is proposed to be achieved through the following objectives:

- to examine the technologies currently linked with the 4IR and used by construction consultants in the industry;
- to investigate the issues that may hinder the construction consultants' strategic application of 4IR technologies; and
- to examine the initiatives necessary to overcome the perceived encumbrances the construction consultants face.

Please note that questions for the virtual interview will be within the stated objectives. Also, your responses will be collated and analysed together with that of other participants. Your responses will be handled with the greatest confidentiality.

Hence, your valuable time and other inputs in answering the questions and contributions will be highly cherished. Note, findings from this study will be shared with the participants that indicate interest after the virtual face-to-face interview via email address to be supplied by them.

Regards.

Yours faithfully,

(Research Co-ordinator)

Basic questions for the participants

(1) Please, for record purposes, what is the name of this firm?

(2) What service does the organisation render?

(3) What is your position in this firm and how long have you been working?

(4) Please, are you knowledgeable regarding the fourth industrial revolution (4IR) or Industry 4.0 concerning the construction sector?

(5) Please, from your experience, can you identify technologies that are currently linked with the 4IR and used by construction consultants in the construction industry?

(6) Please, can you give an example(s) of how these technologies are used by the construction consultants/design team?

(7) Do you think these technologies enhance service delivery to their clients?

(8) If yes to Question 7, can you explain?

(9) From your perception, do you think the usage of these 4IR technologies faces some challenges?

(10) If yes to Question 9, can you identify them?

(11) Do you think these encumbrances can be mitigated to improve the usage of 4IR technologies among the construction consultants?

(12) If yes to Question 11, can you give a practical example of how these challenges can be mitigated?

(13) What role do you think the government can support and create the enabling environment to build a more resilient construction sector via 4IR technologies?

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