Assessment of Industrial Revolution on Building Production Management

Ayodele Christianah AJAO[1*]
John Adekunle AREMU[2]
Sherifat Omowumi SIYANBOLA[3]
Kabiru Okegere TIJANI[4]
[1, 2, 4] Department of Building Technology, The Oke-Ogun Polytechnic, Saki
[3]Department of Architectural Technology, The Oke-Ogun Polytechnic, Saki
[1] ayokola1@gmail.com, +2348027278257

***Corresponding Author**

Abstract
Industrial Revolution (IR) has caused tremendous changes in technology which have greatly affected the construction industry and her products. With the current changes in technology, the mode of operation of construction industry has been changed. The efforts put in place in meeting the demand for the products of construction industry particularly building has revealed the extent at which the construction of building has adapted to technological changes brought about by industrial revolution. All the construction processes of building are no longer with stress, but at ease with the use of machines and other means of intelligent networking and the use of managerial policy in order to improve the quality of the building. This paper aims at assessing the evolution of industrial revolution, its impact on building production management and challenges confronting the evolution. The paper adopted literature review and finds that, though, introduction of industrial related technology in management of building production harnesses effective use of resources and improved the quality of building produced in terms of cost, time and workmanship, there are some challenges slowing down the full processes in building production. The paper concludes that all construction stakeholders should implement industrial revolution techniques, system and application so as to drive production system of the industry to match with the other industries by improving education and training so as to meet up with the demand of modern technologies.

Keywords: Industrial Revolution, Construction, Building, Production, Management

Introduction
The scope of work of the construction industry is diverse and ranges from the construction of residential and industrial buildings, and commercial projects to the construction of infrastructures (Keogh & Smallwood, 2021). It is reported to be among the biggest global sectors, and the foundation it produces is the pillar of economic growth and competitiveness with 6% of global GDP and more than 8% of GDP in developing nations, by the World Economic Forum (WEF, 2016). The Industry creates new jobs, drives economic growth, and provides solutions to address social, climate and energy challenges (Onyia & Oguaghamba, 2020). The Construction Industry is prominently linked with other sectors, and its impact on GDP and economic development goes well beyond the direct contribution of construction activities (Castagnino, Rothballer, Abreu, & Zupancic, 2018; Onyia & Oguaghamba, 2020). Building production management as one of the activities of construction industry is currently witnessing the fourth industrial revolution where enormous transformation in terms of technologies has occurred which has brought rapid development on the industry performance through constant changing technology (Lau, Aminudin, Zakaria, Saar, Abidin, Roslan, Hamid, Zain, Lou & Shaharuddin 2019).

The fourth industrial revolution (FIR, 4IR or 4,0) started in the year 2000. It can be referred to as Internet and Renewable Energy. The 4IR is a term coined in 2016 by Klaus Schwab, Founder and Executive Chairman of the World Economic Forum (Schwab, 2016; Ojo 2022). It is characterized by the convergence and complementary of emerging technology, biotechnology, new materials and advanced digital production (ADP) technologies. The latter includes Three Dimension (3D) printing. Human-machine interface (HMIs) and artificial intelligence (AI), which are already transforming the global industrial landscape (UNIDO- Industrial Development Report, 2020) in Lavapa and Delera (2021) and Ojo, (2022). Its pioneers came from diversified fields including business, academia, and politics. The federal government of German embraced the idea in its High-Tech Strategy for 2020 (Mohamed, Ismail, and Abdullah, 2020).

Most organizations demand upgrading of some platforms on Quality Management Systems (QMS) and supply chain to convert the industry into a smart factory that will have the capacity of meeting the requirements of the sector. Some of the technological changes include substituting old equipment with modernized ones, Artificial Intelligence (AI), implementation of sensors, enterprise-level solution platforms, and Machine Learning (ML) (Nagy, Ol´ ah, Erdei, M ´at ´ e, and Popp, 2018 and Mohamed *et al.*, 2020).

Building Production Management is referred to as levels of utilization of materials, machines, and labour in building construction to achieve a specific goal. This is achieved by controlling quality, speed, dependability, flexibility, and cost (Henrich & Koskela, 2005). The building production mangers and quality management personnel are making appropriate decisions that will see smooth transition to digital technology to improve efficiency and quality of building production. Also, the quality management personnel are trying to derive effective methods of embracing internal and external data and technology and utilize them in order to cultivate a culture of innovation while enhancing the overall quality of building production.

Evolution of 4IR has introduced construction digitalization, where Building Information Modeling (BIM) has become the center of the project (Raihan, Ali, Petra, Maresova, Ondrej & Oladipo, 2019). Despite the contributions of 4IR in construction activities, the construction sector has been slow to completely accept newly evolving technology adoption (Ghada, 2021). This can be traced to a lack of on-site engagement, a workforce with a limited preference for modern technologies, and fractured relations (Ghada, 2021). Lau, *et al*., (2019) added that, slow action of construction sector in investing in 4IR indicates that stakeholders have least interest in investing in the new technologies.

Many research works have been carried out on 4IR and construction industry but, not many studies have identified and assessed the efficacy of the Fourth Industrial Revolution on building production and the principles mitigating its adoption. On this ground stands this paper to identify the factors and challenges confronting the construction sector in adopting 4IR and assess the effects on building production.

Significance of the Paper

This paper can contribute in several ways to help the construction companies that want to remain competitive in the national and international market, and embracing new era technologies as one of their missions. First, companies can access a general idea of Industry 4.0 and its main technologies in building production and its management. Being familiar with the latest technologies empowers companies with a great management vision. Also, this paper can provide a vision for companies to assess their process digitization level. Finally, they can come to the idea that combining one of these technologies can provide more extensive benefits in different dimensions.

3. Methodology

The method used in this study is review of literatures based on articles of fourth industrial revolution in construction as it relates to building production management. The term "fourth industrial revolution" was described as well as the technologies involved in construction towards building production. Challenges confronted by construction sector in adopting the system (4IR) and the effects were also reviewed.

Literature Review

Construction 4.0

Construction 4.0 (Fourth Industrial Revolution - FIR) is an innovation platform for the built environment (Sawhney, Riley, & Irizarry, 2020). It is described as a revolutionary paradigm in which three transitions occur: industrial production and construction, cyber-physical system, and digital technologies. BIM (building information system), CDE (common data environment), cloud-based systems engineering, AR/VR (augmented reality/virtual reality), big data and analytics, block chain, and laser scanners are all instances of emerging innovations. Robotics and automation, sensors, the Internet of Things (IoT), industrial manufacturing, off-site and on-site construction, employees using wearable sensors, and devices fitted with sensors all fall into the category of cyber-physical systems (Taher, 2021). R¨ubmann, Lorenz, Gerbert, Waldner, Justus, Engel, and Harnisch, (2015) in the study on industry 4.0, the future of productivity and growth in manufacturing industries established nine technologies that will mark complete transformation into the industry 4.0. These include automated robots, integrated horizontal and vertical systems, cyber security, 3D printing (additive production), big data analysis, simulation, industrial IoT, cloud-based services, and augmented reality (Mohamed *et al.*, 2020).

FIR in Building Production Management

Drones

Drones are mostly used in the construction industry for observation and tracking purposes during survey work, construction, and facilities operations (Zaychenko, Smirnova and Borremans 2018).

Three-dimensional (3D) Printing

The method of making a dynamic, physical 3D structure from a CAD model is known as 3D printing or additive manufacturing. 3D printing has been the focus of 25 years of research and development, and it isnow used in several fields, including aerospace, vehicles, and medicine (Chua and Leong, 2014). The construction industry is still looking at 3D printing, but mostly for small to medium-sized projects right now. These technologies have recently ignited attention in the building sector, particularly with cement, lending to its potential to substitute human workers with automated manufacturing, enabling substantial saving of time as well as personalized and scalable construction manufacturing (Wang, Wu, & Wang, 2016).

Building Information Modelling (BIM)

BIM is a computer program that allows all stakeholders in the construction process to generate, transfer, exchange, and communicate data (Alaloul, Liew, Wan, Zawawi, Mohammed & Adamu, 2018). BIM has been critical in the building industry's digitalization.

Overall, BIM –specifically 5D planning and budget integration results in substantial cost savings (direct costs, efficiency, delays, protection, and image) across the entire construction value chain (design, construction, operations and destruction). In other words, BIM (Building Information Modeling) can enhance operating processes over the lifespan of a construction project (Wyman, O. 2018). Today, Building Information Modeling (BIM) is considered to be the central technology for the digitization of the construction manufacturing environment (Li, Hou, Yu, Lu, and Yang, 2017).

Robotics

This technology is widely used in building production management, particularly in the assembling of high-rise buildings. For example, the SMART machine built by SHIMIZU in Japan was also used to create a 30-story office tower. Furthermore, robots can execute various building operations like painting, brick overlaying, and earthwork (Mohamed *et al.*, 2020).

Artificial Intelligence (AI)

AI is a concept that refers to a computer that mimics human cognition (Rao, 2020). Throughout the construction industry, 4.0 AI can be used in adaptive vision systems to distinguish different aspects on a construction site, as well as voice and recognize patter to track the progress of construction workers in full detail (Bryson & Winfield, 2017). It can forecast several anomalies involved in building, architecture, construction, and service. (Li et al., 2017).

Internet of Thing (IoT)

This allows for the fast storage, processing, and sharing of data. It's generally acknowledged as one of the most critical fields of future technology, and it's gaining a lot of interest from sectors (Lee and Lee, 2015; Ghada, 2021). In the context of construction 4.0, the Internet of Things (IoT) is being used to incorporate goods like Wireless sensor networks, middleware, cloud computing and IoT application software (Ghada, 2021).

Blockchain Technology

Blockchain was proposed in 2008 and launched in 2009 (Wang, Zheng, Xie, Dai, & Chen, 2018). Blockchain is an essential digital ledger of transaction that is duplicated and distributed across the entire network of the computer systems (Wang *et al*., 2018). Construction has always been a collective procedure involving a larger or smaller group of participants in which communication technology has a big influence on connections between those involved throughout history (Turk & Klinc, 2017). Application of blockchain in construction has only recently begun and some are utilizing it to securely and widely transmit the sensor data from structures (Wang et al., 2018). Supply chains in the construction sector have a decentralized and fragmented structure, which works well with blockchain's decentralized ledger technology (Shojaei, 2019). Petersson and Jönköping, (2018) opined that blockchain technology can offer the infrastructure required to enhance material traceability in a secure and reliable manner and progress the circular economy. There are five areas where block chain technology can be applicable in the built environment which are; smart contracts, supply chain management, BIM, facility management and sustainability (Shojaei, 2019).

Building Production and 4IR

Building construction is one of the essential community conditions that ensure a healthy quality of life and well-being for residents in any country (Chan & Adabre, 2019). In comparism with other industries of the economy, like manufacturing, banking, and health sectors, there has been a lack of accurate standards and efficient project management practices in the building industry due to the multifaceted nature of the industry (Yahya, Abba, Mohammed & Yassin, 2019: Guo & Zhang, 2022; Oke, Kineber, Olanrewaju, Omole, Jamir. Samsurijan, & Ramli, 2022). With this, there is need for revolutionizing the building field by adopting effective and sustainable building practices. Furthermore, building professionals cannot measure the environmental influences of buildings as they accrue through construction. Therefore, the Fourth Industrial Revolution can be combined with the sustainability method at the preliminary and design phases of a project (Oke *et al.*, 2022). Oke *et al.,* (2022) established that, many industries have embraced these innovations in full, while the building industry is still lagging. Many developed countries and their construction industries have been making use of some of these innovations due to their advantages. Such countries as China, Japan, the USA, and the UK, to mention a few (Liu & Xu, 2017; Oke *et al*., 2022) fall within this bracket. The case is different for most African countries, especially Nigeria. The commonest and most used form of 4IR present in the Nigerian building industry is building information modeling (BIM), and even this application is yet to be fully adopted (Oke *et al*., 2022).

Challenging Factors Affecting Adoption of 4IR in the Construction Industry Towards Building Production Management

Despite the usefulness and adequacies in the use of 4IR in building production, there are still some challenges facing its adoption. The challenging factors affecting adoption of 4IR in the construction industry towards building production management can be classified into economic, human, political and legislation, technological, and social.

Economic Factors

It has been identified that the high cost of acquiring these technologies and training the professionals to operate the 4IR technologies are high. Consequently, most stakeholders and organizations struggle to adopt these technologies (Ojo, 2022). Lau, et al., (2019) added that, lack of designed public policies to promote 4IR, lack of clear digital operation vision, lack of support, inadequate knowledge of benefits of 4IR, inefficient regulatory framework and decentralized organization of the industry have been some of the economic challenges preventing the adoption of 4IR in building construction. Installation of infrastructures also requires the financial strength of stakeholders (Ojo, 2022).

Human Factors

The human factors include the lack of awareness, technical know-how and the existing culture. The existing culture in the construction industry makes it difficult for the adoption of new ones as existing stakeholders find it difficult and resist change (Ejohwomu, Adekunle, Aigbavboa & Bukoye 2021). Also, investing in new technologies required the workers that can handle it skillfully (Lau, *et al*., 2019).

Political and Legislation Factors

Lack of public policies designed to promote industry 4.0, re-evaluation and re-engineering of business practices, lack of support/leadership from top management, lack of understanding of the strategic importance of industry 4.0, decentralized organization of the construction companies, as well as the temporary nature of the construction (building) projects, cyber security, virus attacking data and lack of consistent in BIM (Lau, *et al*., 2019).

Technological Factors

Many technological factors affecting adoption of 4IR in building production by the construction stakeholders identified by Lau, *et al*., (2019) include unreliable broadband connectivity or the lack of access to high-bandwidth connectivity for collaboration applications, technology changes over time and has to be updated constantly, higher requirements for computing equipment and the problem in managing these large quantities of data requires new modeling techniques and data formats. Nagy *et al*., (2018) reported the study carried out by Fraunhofer Institute in 2013 on the review of the potential for growth and expansion of companies using 4IR technologies. The findings of the survey indicated five main technologies areas that affect the growth of industries which are already into 4IR technologies. These include embedded systems, strong networks, IT security, smart factories, and cloud computing (Mohamed *et al*., 2020).

Social Factors

Low awareness of Industry 4.0 and its applications, lack of enhanced skills for the applications, process-dependent systems that make greater use of technology as a major challenge for existing employees, fear of employees about the adoption of new technologies as they might be replaced by machines, computers or robotics which might result into job-loss, low level of readiness of the staff to be trained and lack of understanding the interplay between technology and human (Lau et al., 2019; Ejohwomu, et al., 2021).

Effects of 4IR on Building Production

It was discovered that, fourth industrial revolution has both negative and positive impacts on building production. The positive effects include higher productivity. FIR has increased the level of productivity in building production; since all activities are no more manually carried out (Ejohwomu, et al., 2021, Ojo, 2022). Alaloul et al (2018) added that, industrial revolution has improved the quality of building production. The projects are delivered on time and at minimum cost due to the used of improved technological instruments. It also gives room for adequate quality control during construction and also helps in effective use of resources and quality workmanship (Maresova, Ivan, Libuse, Martina, Ehsan, Ali & Ondrej 2018). Raihan (2019) also outlined some effects of 4IR to the construction industry to be an efficient instrument in communication and effective in building client/contractor relationship.

In the same vein, Onyia and Oguaghamba (2021) added that, Technologies of the Fourth Industrial Revolution can offer new tools for city authorities, private developers and residents to properly plan, visualize and manage urban development and operations (smart planning and construction). Drones, sensors and big-data powered simulations aided by artificial intelligence can simplify these processes and improve engagement with citizens leveraging new ways of generating and using data. BIM, advanced materials, 3D printing and artificial intelligence can support intelligent building design and streamline construction contracting. Other solutions include next-generation building codes using digital design and nano-materials to radically reduce embodied carbon in production, and off-site pre-and modular fabrication improving construction efficiency and flexible, reusable building parts.

Conclusion and Recommendation

FIR is a relatively new research field pursued mostly by developed western countries. The adoption of FIR technologies has implications for the whole construction industry, the involved companies, the environment, and employees. It has improved productivity, efficiency, quality, and thus improved the poor image of the construction industry in building production management. The digital transition necessitates the use of a company's innovative ability, as well as new business models, tactics, organizational improvements in resources management, production processes, and overall project management practices, technology styles, and physical infrastructures.

Despite the benefits of FIR, most construction firms/companies have not adopted it. Some that have adopted it are still finding it difficult to implement it. Therefore, the construction firms/companies should go into implementing FIR technologies and undergo digital transition aiming at improving management of building production. Also, Extra efforts among academicians and industry players are required to implement FIR amidst complicated environment of the construction industry and push its traditional borders. The adoption of technologies is key to the optimal operation of the construction industry for the best performance of managers in building production. Adequate skills for utilizing the technologies are required, which necessitates technological transfers in the form of labor development, skills transfer, training, and retraining to fully explore the capacity of new technologies for improved management performance.

The construction stakeholders will need to come together, freely exchange information and collaboratively solve issues as they occur, to maximize the benefit of free-flowing information and capture any disparity in design and construction and fed back into the project's digital environment to allow designers and contractors to assess and make real-time decisions on remedial action to prevent costly mistakes from occurring.

References

Aghimien, D., Aigbavboa, C., & Matabane, K. (2019). Impediments of the Fourth Industrial Revolution in the South African Construction Industry, In Ejohwomu O., Adekunle S.A, Aigbavboa C.O., and Bukoye O. T (2021).The Construction industry and the Fourth Industrial Revolution: Issues and Strategies available at: https://www.researchgate.net/publication/356387854

Alaloul, W. S., Liew, M. S., Wan Zawawi, N. A., Mohammed B. S. and Adamu, M. (2018). An Artificial Neural Networks (ANN) Model for Evaluating Construction Project Performance based on Coordination Factors. *Cogent Engineering, 5* (1).

Bryson, J. J. and Winfield, A. F. T. (2017). Standardizing Ethical Design for Artificial Intelligence and Autonomous Systems. *Computer, 50*(5), pp: 116-119.

Castagnino, S., Rothballer, C., Abreu, J. and Zupancic, T. (2018). Six Ways The Construction Industry Can Build For The Future, World Economic Forum, Published 15 March, 2018. https://www.weforum.org/agenda/2018/03/how-construction-industry-can-build-its-future/ (Accessed July 3, 2019) cited in Onyia M.E. & Oguaghamba A. O. (2020). Positioning the Nigerian Engineering and Construction Industry in the Fourth Industrial Revolution. "2020 LGT-ECE-UNN International Conference: Technological Innovation for Holistic Sustainable Development (TECHISD2020)".

Chan A. P., & Adabre M.A. (2019). Bridging the Gap between Sustainable Housing and Affordable Housing. The required Critical Success Citeria (CSC). *Build Environ.* 151, pp: 112-125, cited in Oke, A. E., Kineber, A.F., Olanrewaju, O.I., Omole, O., Jamir. P.S., Samsurijan, M.S. & Ramli, R.A. (2022). Exploring the 4|R Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective-A Structural Equation Modelling Approach. *Sustainability 2023*, 15(1), p: 468; https://doi.org/10.3390/su1500468

Chua, C. K. & Leong, K. F. (2014). 3D Printing and Additive Manufacturing4th ed. World Scientific Publishing Co. Pte. Ltd

Ejohwomu, O., Adekunle S. A, Aigbavboa C.O., and Bukoye O. T (2021).The Construction Industry and the Fourth Industrial Revolution: Issues and Strategies. Available at: https://www.researchgate.net/publication/356387854.

Ghada, T. (2021): Industrial Revolution 4.0 in the Construction Industry: Challenges and Opportunities. *Management Studies and Economic Systems (MSES), 6* (3/4), 109-127.

Guo, K. & Zhang, L. (2022). Multi-Objective Optimization for Improved Project Management: Current Status and Future Directions. *Autom. Constr.* P: 139, 104256, cited in Oke, A. E., Kineber, A.F., Olanrewaju, O.I., Omole, O., Jamir. P.S., Samsurijan, M.S. & Ramli, R.A. (2022). Exploring the 4|R Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective-A Structural Equation Modelling Approach. *Sustainability 2023, 15*(1), pp: 468; https://doi.org/10.3390/su1 501 0468

Henrich, G. & Koskela, L. (2005). Improving Production Control: Initial Overview. "5th International Postgraduate Research Conference. SCRI/BuHu - Salford – UK".

Keogh, M. and Smallwood J.J. (2021). The Role of the 4th Industrial Revolution (4IR) in Enhancing Performance within the Construction Industry IOP Conf. Ser.: Earth Environ. Sci. 654 012021

Lavapa and Delera (2021). What is the Fourth Industrial Revolution? Available at https://iap.unido.org/articles/what-fourth-industrial-revolution

Lee, I. & Lee, K. (2015). The Internet of Things (IoT): Applications, Investments, and Challenges for Enterprises. *Business Horizons, 58*(4), 4, pp: 31–440.

Li, B.-H. Hou, B.-C. Yu, W.-T., Lu, X.-B. and Yang, C.-W. (2017). Applications of Artificial Intelligence in Intelligent Manufacturing: A Review. *Frontiers Info Technology Electronic Engineering,* 18, pp: 86-96.

Liu, Y. & Xu X. (2017). Industry 4.0 and Cloud Manufacturing: A Comparative Analysis. *J. Manuf. Sci. Eng. Constr. Archit. Manag,* p: 139, https://doi.org/10.1115/1.40347667, cited in Oke, A. E., Kineber, A.F., Olanrewaju, O.I., Omole, O., Jamir. P.S., Samsurijan, M.S. & Ramli, R.A. (2022). Exploring the 4|R Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective-A Structural Equation Modelling Approach. *Sustainability 2023, 15*(1), p: 468; https://doi.org/10.3390/su1 501 0468

Maresova, P., Ivan S., Libuse S., Martina H., Ehsan J., Ali S. & Ondrej K. (2018). Consequences of Industry 4.0 in Business and Economics. *Economies* 6: 46.

Mohammed, B., Ismail, S. and Abdullah, D. (2020). Industrial Revolution (IR4.0) Impact on Management. DOI: 10.5220/0009865501040109, "In Proceedings of the International Conference on Creative Economics, Tourism and Information Management (ICCETIM 2019) - Creativity and Innovation Developments for Global Competitiveness and Sustainability", pp: 104-109

Nagy, J., Ol´ ah, J., Erdei, E., M ´ at ´ e, D., and Popp, J. (2018). The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain the Case of Hungary. *Sustainability*, *10*(10), p: 3491.

Ojo, O.J. (2022). Environmental Safety and Security in the Era of Fourth Industrial Revolution. "Lead Paper presented at the National conference on Environment, Safety and Security Management in the era of Fourth Industrial Revolution", Federal Polytechnic, Ado-Ekiti 6th- 7th September.

Oke, A. E., Kineber, A.F., Olanrewaju, O.I., Omole, O., Jamir. P.S., Samsurijan, M.S. & Ramli, R.A. (2022). Exploring the 4|R Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective-A Structural Equation Modelling Approach. *Sustainability 2023, 15*(1), p: 468. https://doi.org/10.3390/su1 501 0468.

Onyia, M.E. & Oguaghamba A. O. (2020). Positioning the Nigerian Engineering and Construction Industry in the Fourth Industrial Revolution. "2020 LGT-ECE-UNN International Conference: Technological Innovation for Holistic Sustainable Development (TECHISD2020)".

Petersson, E., & Jönköping, K. (2018). Impacts of Blockchain Technology on Supply Chain Collaboration A Study on the Use of Blockchain Technology in Supply Chains and How it Influences Supply Chain Collaboration.

Raihan, M. Ali, S. Maresova, P. Ondrej K. & Oladipo,O.O (2019). Industry 4.0 for the Construction Industry: Review of Management Perspective. Economies July 2019, available at https://www.researchgate.net/publication/334231324.

R¨ußmann, M., Lorenz, M., Gerbert, P.,Waldner, M., Justus,J., Engel, P., and Harnisch, M. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. *Boston Consulting Group, 9*(1), pp:54–89.

Sawhney, A. Riley, M. and Irizarry, J. (2020). *Construction 4.0: An Innovation Platform for the Built Environment*; Routledge: New York, NY, USA, ISBN 978-0-429-39810-0.

Schwab, K. (2016). The Fourth Industrial Revolution. What it Means and How to Respond. Available at https://w.w.w.weforum.org/agenda/2016/01fourth-industrial-revolution-what-it-means and -how-to-respond.

Shojaei, A. (2019). Exploring Applications of Blockchain Technology in the Construction Industry. "Proceedings of International Structural Engineering and Construction", *6*(1).

Turk, Ž., & Klinc, R. (2017). Potentials of Blockchain Technology for Construction Management. *Procedia Engineering*, 196, pp: 638–645.

Wang, H., Zheng, Z., Xie, S., Dai, H. N., & Chen, X. (2018). Blockchain challenges and opportunities: a survey. *International Journal of Web and Grid Services, 14*(4), p: 352.

Wang, J., Wu, P. and Wang, X. A. (2016). Critical Review of the Use of 3-D Printing in the Construction Industry. *Automation in Construction*, 68, pp: 21-31.

World Economic Forum (2016), Shaping the Future of Construction: A Breakthrough in Mindset and Technology, Retrieved June 28, 2019 https://www.weforum.org/reports/shaping-the-future-of-construction-a-breakthrough-in-mindset-and-technology cited in Onyia M.E. & Oguaghamba A. O. (2020). Positioning the Nigerian Engineering and construction Industry in the Fourth Industrial Revolution. "2020 LGT-ECE-UNN International Conference: Technological Innovation for Holistic Sustainable Development (TECHISD2020)".

Yahya, M.Y., Abba, W.A, Mohammed S. &Yassin, A.M. (2019). Contributing Factors of Poor Project Performance in Nigeria. *Int. J. Prop. Sci.* 9, pp: 1-11, cited in Oke, A. E., Kineber, A.F., Olanrewaju, O.I., Omole, O., Jamir. P.S., Samsurijan, M.S. & Ramli, R.A. (2022). Exploring the 4|R Drivers for Sustainable Residential Building Delivery from Social Work Residential Perspective-A Structural Equation Modelling Approach. *Sustainability 2023, 15*(1), p: 468; https://doi.org/10.3390/su1 501 0468.

Zaychenko I., Smirnova A. and Borremans A. (2018). Digital Transformation: The Case of the Application of Drones in Construction. "MATEC Web of Conferences".