

Level of Application of Technologies for Health and Safety Management on Construction Sites in Lagos State, Nigeria

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Abstract:

Safety of workers is a grave concern to all stakeholders on construction sites, as construction operations are mostly carried out in hazardous environments due to complexity of construction projects. Research findings revealed the effectiveness of use of technologies in Health and Safety (H&S) management. However, the rates of accidents are still high on construction sites. The objective of this study therefore is to determine the level of application and barriers to the application of technologies for H&S management in Lagos, Nigeria with a view to enhancing safety practices. A questionnaire was designed to collect information on level of application and barriers to the application of technologies for H&S management. Copies of questionnaire were administered to active construction firms in Lagos. Pilot survey revealed 135 active firms at the time of carrying out the study. Purposive sampling method was used to distribute the questionnaire. Findings revealed that application of technologies in H&S management in construction is relatively low. Online Database and Internet of Things were the most used technologies while Robotics and Automaton were rarely used. Capital intensive and low technical ability were the major barriers affecting the application of technologies in construction. From the findings, contracting firms need to increase allocation of capital for acquisition of new technologies and train their workers on the use of these technologies to enhance their safety.

Keywords: Construction sites, Health & Safety, Safety Practices, Technologies, Workers.

Introduction

Construction industry has witnessed a lot of challenges in the area of Health and Safety (H&S) management (Yap *et al.*, 2022). The industry continually records injuries and fatalities which results into an unsafe place for the workers (Kang & Wu, 2020). Particularly in developing countries like Nigeria, construction workers are being exposed to injuries and fatalities due to complexity of construction operations. Against this background, researchers are continuously seeking for alternative approaches that could help the construction industry to enhance its safety performance (Howard *et al.*, 2018; Jebelli *et al.*, 2019; Demirkesen & Tezel 2021; Dobrucali, *et al.*,

2023). From the study carried out by Zhou *et al.* (2013), it was discovered that the rate of reporting the application of technologies as an alternative approach to safety of workers on construction sites increased roughly three times from 2000 to 2010. The consistently increasing in the study of technologies for H&S management in construction was confirmed by Nnaji & Karakhan (2020). This is an indication that various technologies reducing the problems of H&S management in construction have emerged and been reported.

The application of these technologies according to Yap *et al.* (2022) enhances workplace safety by recognizing and

eliminating risks that are unknown and unseen by the workers early enough. It is impossible to completely eliminate human errors on construction sites by adopting technology, but it is an effective technique for reducing the risk. According to Howard *et al.* (2018) technology is an alternative technique to ensure that construction sites are safe for the workers. Despite several publications on the benefits of applying technologies to H&S management on construction sites, the rates of accidents and injuries are still high. From the available records, not too much attempt has been made to assess the level of application of these technologies and barriers of applying these technologies to the H&S management on construction sites. This study therefore aimed at examining level of application and barriers to application of technology for H&S management in construction in Lagos State, Nigeria with a view to enhancing safety practices on construction sites. The objectives are to identify various technologies applicable to construction H&S management, to determine level of application and to examine the barriers to the application of the technologies on construction sites.

Literature Review

Health and Safety Challenges in Construction

Construction projects globally are increasingly becoming more intricate, varied and require technical, interdependent, specialized operations (Okoye & Okolie, 2014). The complexity and fragmented nature of these operations requires the involvement of different types of workers and involvement of different types of machineries, equipment, tools and materials on construction sites. The movements during construction operations are sometimes without a pattern, thus, exposing workers to various degrees of accidents. According to Yap *et al.* (2022), injuries on construction sites are as a result of conventional work processes, too much human involvement with little or no technologies involved, together with unsafe attitudes of construction workers. Other

causes according to Whittingham (2014) are: improper use of equipment and machines, workers have no regards for safety rules, no clear and understanding information from instructions and safety manuals, disorganized and untrained site workers on safety practices and little or no H&S management. Findings from reports on H&S management revealed that the rate of accidents on construction sites is high compare to other industries in the most countries (Umeokafor *et al.*, 2014; Okoye *et al.*, 2016). Whenever accidents occur, sites are often closed down for investigation, there is loss of time/output and loss of reputation on the part of the contracting firms. Payments are made to compensate the injured and for burial in case the accident leads to death. Thus, clients and construction organizations are required to implement good safety management practices to minimize accidents on construction sites. Every stakeholder and party to a construction contract has a role to play in terms of ensuring that H&S is taken seriously on sites.

Technologies for Health and Safety Management on Construction Sites

Previous researches on H&S management on construction sites emphasized that the adoption of technologies can greatly reduce the rate of accidents hereby enhance workers' safety (Nnaji & Karakhan 2020; Yap *et al.*, 2022). In this regard, application of technologies creates safely and conducive work environments on construction sites. According to Xu *et al.* (2020), safety on sites is enhanced by using information from surveillance cameras for exploring the risks on the sites and providing warnings against such risks. With technologies, operation time and errors are reduced (Edirisinghe, 2019; Pan *et al.*, 2021). Findings from several studies have recognized technologies that are effective in reducing or eliminating the challenges of H&S management on construction sites. The recognized technologies include robotics, drones, Building Information Modeling, 4D CAD, Virtual Reality, Internet of Things, unmanned machinery, Augmented Reality and Radio-Frequency

Identification (Zhou *et al.*, 2013; Guo, 2017; Delgado, 2019; Uguina *et al.*, 2019). However, using these technological interventions to ensure safety at construction sites is an effective approach towards H&S management.

Robotics are mostly used in dangerous and strenuous operations. According to Li (2018), robots are mostly used in place of workers on speedy construction activities that are dangerous and repetitive in nature. Such activities always put the workers on risk of overstretched muscles, tendons and ligaments. Robots are controlled by computers and used autonomous installation to and carrying heavy construction materials (Waidyasekara, 2020). According to Ruggiero *et al.* (2016), various robots have been developed and emerged. Some of the emerged robots that can be used on construction sites are exoskeletons, welding robots and forklift robots.

Online system is a used for several aspects of construction H&S such as training on identifying risks, monitoring, evaluation and safety inspections. According to Zhou *et al.* (2012), potential hazards on construction sites can be identified using online databases. Web safety monitoring system displays safety warning signs whenever risks are detected on sites. Data can easily be searched, uploaded, collected and documented through remote internet access. To enhance decision making during the evaluation process, Artificial Intelligence is applied to the online system. Internet of Things (IoT) are technologies that are connected to wired and wireless network through embedded tools and devices. IoT monitors site operations that need constant and close attention. GPS, smart sensors and wireless networks are used to monitor equipment and site workers and also inform them about potential hazards. Sensors are used to collect information on H&S, the data collected are stored, analyzed and reviewed through clouds and then generate reports on dangerous activities and near-miss accidents.

Building Information Modelling (BIM) is one of the emerged technologies that has been increasingly used in recent years within the construction industry (Azhar, 2011). BIM provides significant opportunities in hazards identification and hereby eliminate H&S issues on sites. According to Kiviniemi, *et al.* (2011), BIM-based safety exhibits an efficient and effective technology for interactions on safety-related issues on construction sites with the project participants. 3D CAD are used by safety experts in the early stages of construction for planning and for identification of potential hazards in construction. 3D CAD can also be used for accident investigation and facility maintenance (Rajendran & Clarke, 2011). According to Azhar, *et al.*, (2012), 4D CAD displays safety components and high-risk areas during the project's life cycle. The application of a 4D visualization framework for H&S management was proposed by Zhou *et al.* (2013).

In H&S management, Radio-Frequency Identification (RFID) technology has been used to gather H&S information with the use of radio frequency waves. These waves identify the status of workers, equipment and materials on construction sites by transmission and retrieval of the stored data. (Zhou *et al.*, 2013). Virtual Reality (VR) is being used in construction as an effective tool for safety training. VR training helps workers to build their confidence in the knowledge of the use, maintenance and replacement of personal protective equipment (Li & Leung, 2017). In addition, the use of VR enables the safety training exercises to be carried out in the absence of a qualified safety expert by just stimulate the training environment on a personal computer. In contrast to VR which enables computer graphics to simulate safety training, Augmented Reality (AR) intensify reality safety training through the use of technology. According to Patrucco *et al.* (2010), AR brings computer-generated objects into physical environment. It enables the site workers to practice what they were trained without the fear of risk. By stimulating hazardous situations, workers

will know the consequence of not following safety rules. Hand-on experiences will enable them to memorize the things they need to stay safe.

Barriers to Application of Technologies for Health and Safety Management in Construction

Despite the advantages of adoption of technologies in H&S management in construction, several barriers to the application of these technologies were also identified. In the study carried out by Nnaji & Karakhan (2020), thirteen (13) barriers were revealed, the five most critical barriers were: requirement for extensive upfront investment, need for extensive training, unavailability of technical support, reliability of the technology and low client demands for their use. According to Rohana (2012), the identified barriers are: obligation to spend a lot of money, requirement for technical knowledge and equipment, non-compatible with existing practices, situation of the workforce, and nature of the industry.

In another study carried out by Yahya *et al.* (2019), the barriers to the application of technology on construction sites are: exorbitant cost of acquisition, maintenance and updating the technologies. According to Edirisinghe (2019), technical limitations, conformity to standards, random technology design, development and execution are the barriers associated with application of technology for H&S management. According to Osunsanmi *et al.* (2020), the use of technology on construction sites is hampered by acquisition charges and low technical knowledge. In the work of Demirkesen & Tezel (2021), barriers such as lack of conformity to standards, legal and contractual issues and cost of execution were identified. Study carried out by Bademosi & Issa (2021) also revealed barriers such as cost of acquiring the technology, lack of legislation, data insecurity and no guarantee on the privacy of workers personal data.

Several other related studies revealed critical factors hindering the application of technologies in construction H&S

management to include high start-up capital, not fully developed technologies, characteristics of the industry, complexity of technology, economic situations, stagnant work efficiency, low budgets for restructuring and a weak culture of innovation (Delgado *et al.*, 2019; Nnaji & Karakhan, 2020; Demirkesen & Tezel, 2021; Yap *et al.*, 2022; Dobrucali *et al.*, 2023).

Research Methods

The main objective of this work is to determine the level of application and barriers to application of technologies in management of H&S in construction. The objective was achieved by reviewing comprehensive literature to reveal the technologies applicable to H&S management and the barriers to their application. The population for the study was construction organizations registered with Lagos State Public Procurement Agency (LSPPA). A total of one hundred and thirty-five (135) copies of questionnaire were administered to the active construction firms using purposive sampling technique. The structured questionnaire was divided into three (3) sections; the first section got information about the respondents. Information such as their education and professional qualifications, their year of experience on construction sites and the numbers of projects handled in the last ten years. The second section of the questionnaire was designed to determine the level of application of technologies for H&S management in construction. A list of technologies revealed from the literature was presented for the respondents to rank the level of application to H&S management in construction. The respondents were asked to rate the variables on a five Likert Scale from 1 = Not applicable; 2 = Seldom applicable; 3 = Moderately applicable; 4 = Often applicable; 5 = Very often applicable. The third section indicated barriers to application of technologies H&S management in construction. The variables were also rated on a five Likert Scale on the level of agreement from 1 = Strongly disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly agree. Data Analysis

was carried out using Relative Importance Index.

Results and Discussion

A total of Seventy-Five (75) copies of questionnaire were retrieved representing about 58% response rate. For any study to be authentic, it partly dependent on the reliability of sources of data for that study. This study therefore sought information about the background of the respondents to ensure the information was reliable. Table 1 reveals the detail background information of the respondents such as their highest academic qualification, their organization types, working experience, number of years that the firm has been in construction business and the numbers of construction projects handled in the last ten years. The results show that majority of respondents have obtained a minimum of first degree (87%), about 70% of the firms have been in construction business for more than 10 years. The respondents mostly work in building and civil engineering organizations

and not less than 74% of them had participated in more than ten projects in the last ten year. These findings revealed a reliable sources of information required.

Level of Application of Digital Technologies for Health and Safety Management in Construction

Literature review identified fifteen (15) technologies that are used in H&S management in construction. The respondents were asked to indicate the level of application of these technologies to H&S management in construction. Relative Importance Index (RII) was used to analyze the ranking. The results of the fifteen (15) technologies as applied in H&S management are presented in Table 2. The table shows that online databases was the most applicable technology with RII of 0.774 and Internet of Things (IoT) was ranked second with RII of 0.763. This finding coincides with the studies conducted by Zhou *et al.* (2012) and Dodge Data and Analytics (2017).

Table 1: Respondents' Profile

Category	Classification	Number	Percentage
Educational Qualification	SSCE	10	13%
	Bachelor's Degree	18	24%
	Master's Degree	42	56%
	Doctoral Degree	5	7%
	Total	75	100%
Number of Years of Firms in Construction Business	0-5years	2	3%
	6-10years	20	27%
	11-15years	16	21%
	16-20years	7	9%
	Over 20years	30	40%
Total	75	100%	
Type of Organization	Building	20	27%
	Civil Engineering	30	40%
	Industrial Engineering	5	7%
	Services Engineering	11	15%
	Others	9	12%
Total	75	100%	
Years of Experience of Respondents	0-5 years	19	25%
	6-10 years	19	25%
	11- 15 years	18	24%
	16-20 years	14	19%
	Above 20 years	5	7%
Total	75	100%	

The studies revealed that online databases are used on construction activities particularly in H&S management. Safety training, identification and monitoring of risks, evaluation and inspections of workers' safety are carried out with the application of online databases. According to Jing *et al.* (2014), IoT are used to monitor equipment and site workers and also inform them about potential hazards. 4D Computer-aided design was ranked third with RII of 0.747 and Wearable and Smart PPE ranked fourth with RII of 0.739. Other commonly used technologies are Geographic Information System (GIS), Smart Sensors and Wireless Networks and Building Information Modeling (BIM) with RII of 0.727, 0.709 and 0.617 respectively. The least used technologies are Robot and Automation (RII=0.452), Augmented Reality (RII=0.469), and Radio Frequency Identification (RII= 0.476). This is in line with the study carried out by Guglielmo *et al.* (2018), the study revealed that application of robotics within construction industry encountered strong resistance and highlighted barriers such as site-related challenges, skeptical attitude, varieties of markets and complexity of the supply chain.

Barriers to Application of Technologies in Health and Safety Management in Construction

The respondents were asked to indicate the barriers to application of technologies in

H&S management in construction using Likert scale 1-5. Finding, as shows in Table 3, revealed that capital intensive is the foremost barrier to the application of technologies for H&S management in construction with RII of 0.853. This finding was in line with the studies carried out by Rohana (2012), Yahya *et al.* (2019), Nnaji & Karakhan (2020), and Osunsanmi *et al.* (2020) that high cost of acquisition affects the use of technologies in construction. The second and third important barriers are low technical ability (RII=0.824) and power supply (RII=0.805).

According to Osunsanmi, *et al.*, (2020), Pradhananga *et al.* (2021) and Yap *et al.* (2022), major challenges to the adoption of technologies for construction safety is technical ability of construction professionals. Power supply as one of the major barriers was reported by Oladapo (2007) that erratic power supply in Nigeria affects the use of technologies. Other barriers are: training and learning issues, low level of understanding of basic requirements and weak innovation culture with RII of 0.797, 0.789 and 0.787 respectively. The least barriers are job security, company H&S policy and safety standard for operation with RII of 0.589, 0.622 and 0.624 respectively.

Table 2: Level of Application of Digital Technologies

Digital Technologies	Relative Importance Index (RII)	Rank
Online Databases	0.774	1
Internet of Things (IoT)	0.763	2
4D Computer-Aided Design	0.747	3
Wearable and Smart PPE	0.739	4
Geographic Information System	0.727	5
Smart Sensors and Wireless Networks	0.709	6
Building Information Modeling	0.617	7
Unmanned Aerial Vehicle	0.585	8
Laser Scanning	0.564	9
Photogrammetry and Sensor-based Technologies	0.558	10
Artificial Intelligent	0.513	11
Virtual Reality (VR)	0.491	12
Radio Frequency Identification	0.476	13
Augmented Reality (AR)	0.469	14
Robotics and Automation	0.452	15

Table 3: Barrier to Application of Technologies for Health and Safety Management in construction

Barriers	Relative Importance Index (RII)	Rank
Capital Intensive	0.853	1
Low Technical Ability	0.824	2
Power Supply	0.805	3
Training and Learning Issues	0.797	4
Low level of Understanding of Basic Requirements	0.789	5
Weak Innovation Culture	0.787	6
Security of Data	0.785	7
Little/No government regulations for use	0.781	8
Low level of Knowledge and Awareness	0.778	9
Mis-management by workers	0.771	10
Climatic Condition	0.768	11
Low Technology Literacy	0.763	12
Unavailability of Standards and Guidelines	0.761	13
Complexity of Supply Chain	0.760	14
Lack of Skilled Personnel	0.757	15
Sustainability Factor	0.753	16
Little/No Maintenance Coverage	0.755	17
Incompatibility and Interoperability Problems	0.738	18
Size of the Construction Site	0.736	19
Resistance to Change	0.733	20
Absence of support from government	0.731	21
Storage of Data	0.725	22
Lack of Decisiveness to use by Employers	0.709	23
Lack of Organizational Structure	0.701	24
Unavailable Locally	0.683	25
Low Return on Investment	0.669	26
Safety Requirements	0.637	27
Safety Standard for Operations	0.624	28
Company Health and Safety Policy	0.622	29
Job Security	0.589	30

Conclusion

Technologies as innovative solution has introduced several benefits to the construction. One of the benefits is in H&S management. This study identified various technologies used in H&S management in construction, revealed their benefits, determined level of application and established the main barriers limiting the application. Using the qualitative and quantitative approaches, findings from the study revealed that there was an average level of application of technologies for health and safety management on construction sites in Lagos state, Nigeria and the commonly used technologies in H&S management are: online database, internet of thing, 4D computer aided Design, wearable and Smart PPE. It was also shown that the major barriers to application of technologies in H&S

management is the acquisition of the technologies which is capital intensive, low technical ability, power supply, training and learning issues. This study therefore recommends that construction firms should augment the allocation of funds to acquire new technologies and train their personnel on the use of these technologies. Government should improve on power supply to enhance the use of technologies for H&S management particularly in construction.

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