ADOPTION OF EMERGING INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) TOOLS FOR IMPROVING HEALTH AND SAFETY MANAGEMENT ON CONSTRUCTION SITES IN NIGERIA

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Abstract
The need for effective management of health and safety on construction sites has always been emphasized by all practitioners in the construction industry in Nigeria and the world at large. The construction industry as a dynamic manufacturing sector is a sector where the most fatal occupational accidents and serious injuries have been recorded. There are various information and communication technologies tools or applications that can improve health and safety management on construction sites. Literatures were reviewed to identify the available ICT tools and applications, their capacities and benefits in improving management of health and safety on construction sites. These identified ICT tools are now typically equipped with touch screen, GPS receiver, gyroscope, accelerometer, and wireless communication capability. The features of the tools enable on-site management processes, such as location-based customized work orders and real time information exchange. A Survey to assess the extent adoption of ICT tools can improve the management of Health and Safety on construction sites in Nigeria was carried out by administering quantitative structured questionnaires to 118 professionals in five (5) selected construction companies in South Eastern states of Nigeria. The responses from respondents were analyzed using Relative Importance Index (RII).Previous studies have shown low application of these tools and applications in health and safety management on Nigerian construction sites. It was recommended that construction companies should train all their health and safety staff to be compliant with these ICT tools and applications for effective occupational health and safety management on construction sites in Nigeria.
Keywords: Health and Safety, Construction, Information and Communication Technology.

Introduction
The construction industry as a dynamic manufacturing sector is a sector where the most fatal occupational accidents and serious injuries have been recorded. It is therefore a great challenge for construction companies to manage occupational health and safety as effectively as possible and to monitor and check compliance with the set health and safety rules and standards. In addition to diversity of construction sites, differences in occupations, technology, tools and materials used, make occupational health and safety management very challenging (Hallowell and Gambatese, 2009). Defective equipment, human behaviour, dangerous work areas and unsafe working conditions are cited as common causes of construction site injuries and fatalities (Li, 2015; Hinze & Teizer, 2011). In the light of these, various types of technologies and interventions have been developed to prevent worker's injuries, accidents and enhance construction job site health and safety (Welch *et al*., 2015; Dodge Data and Analytics, 2017; Zhou, Whyte and Sacks, 2011).

The construction industry has recently witnessed a paradigm shift from traditional paper based method of service delivery to electronic information exchange using information and communication Technology (ICT) at least in the western world like UK and even developing countries like Nigeria (Ibironke et al. 2011). It is therefore evident that the adoption of ICT can enhance construction productivity and improve communications for effective decision making and coordination among construction participants and reduce health and safety (H&S) risk on construction sites if can be applied effectively.
In view of this background, this paper addressed the usefulness of ICT tools and applications in the effective management of health and safety on construction sites which will lead to reduction in rate of accidents, injuries and fatalities on site.

Review of literatures

Information and communication Technology (ICT) gadgets available for H&S management improvement on construction sites.

There has been a rapid increase in the use of emerging technological innovations to enhance health and safety on job sites in recent years. ICT smart gadgets can be classified into ***ICT mobile devices*** and ***ICT Tools*** Afatsawu et al., (2020).
ICT mobile devices include; Personal Computer, laptop, mobile smart phones, tablet, micro phone, walkie-talkie, personal digital assistants (PDA), portable data terminals (PDT).
A variety of tools have been developed to assist contractors to achieve health and safety on their construction projects. Numerous studies have identified the use of digital technologies such as BIM, VR and AR, drones, GIS, automation and robotics, unmanned machinery, sensing and warning technologies, 4D CAD as effective technologies for an accident, prevention and safe project delivery (Zhou *et al*., 2011). Several studies have concentrated on the application of digital technologies such as Virtual Reality (VR), online databases, Geographic Information Systems (GIS), Building Information Modelling (BIM), Unmanned Aerial Vehicle (UAV), 4D Computer-Aided Design (4D CAD), wearable robotics, laser scanning, photogrammetry and sensor-based technologies for accident prevention and onsite safety (Dodge Data and Analytics, 2017; Teizer, 2016; Bock, Linner and Ikeda, 2012; Li and Ng, 2017; Zhou *et al*., 2011).
Haupt, Akinlolu, and Raliile, (2019), categorized these tools into the following groups;

- Peoples Technologies
- Process Technologies
- Environment Technologies

Peoples Technologies

People technologies are digital tools applied to ensure the health and safety of workers by what they wear. Teizer*et al*. (2007) revealed that through the application of emerging technologies in health and safety, construction workers could be provided with layers of protection. Previous research efforts have explored the interaction and collision between heavy equipment and workers on construction sites (Li and Leung, 2017). The awareness of workers and visibility of equipment operators decreases because of the repetitive nature of construction activities (Teizer*et al*., 2007). Numerous studies have identified automation and robotics as effective technologies with good prospects to enhance proactive workers' safety on construction sites (Zhou *et al*., 2011). Tools under this category include;

1. Robotics and Automation

2. Wearable Technology and Smart PPE

Process Technologies

These are digital tools applied to ensure safe construction activities on job sites. At the process level, considerable efforts have been made to promote and ensure health and safety (Zhou *et al*., 2011). These include;

- Online Databases
- Internet
- Building Information Modelling (BIM)
- 3D and 4D CAD

Environment Technologies

Environment technologies are tools adopted to ensure the health and safety of the construction environment. GIS and Global Position Systems (GPS) have been combined to understand issues of construction safety by taking into consideration design information, project structure and impact of construction activities on the external environment (Zhou *et al*., 2011); (Bansal, 2011). Others include;

1. Smart Sensors and Wireless Networks
2. Virtual Reality (VR)
3. Augmented Reality (AR)
4. Radio Frequency Identification (RFID)

These ICT tools and applications has been proven very useful to health and safety management on construction sites.

ICT Tools for Managing Health and Safety in Construction Phase

According to Zhou, Whyte, and Sacks, (2012) Researchers have developed a range of new tools for use in the construction phase to help contractors achieve safety in their projects. Digital technologies, such as the online databases, VR, GIS, 4D CAD, BIM, sensing/warning technologies etc., are widely applied for site hazard prevention and safe project delivery. Most of these technologies are combined with each other in related investigations.

The systems developed through such research are aimed at different levels of project, product, process and operation in construction safety management.

Smart Personal Protective Equipment (PPE)

smart PPE's such as safety vests with sensors and GPS incorporated in them have been designed to protect construction workers during fall accidents (Zhou *et al.*, 2013). Physical processes and gestures such as waving heartbeat are captured and used to control a physical process or external event (Zhang *et al*., 2017). The smart hat or helmet is a warning technology equipped with special lenses,4D augmented reality and a transparent visor. The hat detects potential site hazards and provides instructions and warnings (Teizer*et al*., 2010).

Robotics and Automation

Navon and Kolton (2006) developed a model for automation in monitoring and managing fall hazards in scheduled building construction projects. This model determines high-risk areas in construction activities and gives a graphical presentation on the project's drawings (Army and Zain, 2016). Balaguer*et al*. (2002) proposed the use of ROMA climbing robots for inspection of

steel-based infrastructures in construction. This robotic system is a self-supporting locomotion system that conducts inspections in 3D complex environments and operates similarly to a caterpillar. One of the pioneer automation systems was a masonry robot that used seam adhesive to glue bricks and could lay brick walls up to 8m long. Yu (2009) discovered an automated machine called "Blockbot" which is utilised on-site to erect straight bonded brick walls accurately.Controlled by computers on-site and dependent on advanced detection and control, robots are employed in the autonomous installation and gathering of heavy construction materials, which usually require enormous labor, and to construct structures such as skyscraper towers (Niu*et al*., 2017; Jung *et al*., 2013; Li & Leung, 2017).

Online Databases

Online databases are commonly used in assessing competence of different stakeholders, with research tools designed to enable project safety information queries and communication within companies (Yu, 2009). Online systems have been used to improve several aspects of construction health and safety such as safety training and education, risk identification, safety monitoring and evaluation and safety inspections (Dodge Data & Analytics, 2017).

Online databases have been developed to assess competence and to detect potential risks and hazards. The online system applies Artificial Intelligence (AI) during the evaluation process to support decision making through risk identification and assessment, and information capture and analysis (Zhou et al., 2012). Yu (2009) designed a prototype web tool to assist in the evaluation of potential designers, contractors and coordinators.

The Construction Safety and Health Monitoring (CSHM) system was created as a detector of potential risks and hazards, and a warning sign to areas of construction activities that require immediate corrective action (Cheung, Cheung, & Suen, 2004). Leveraging the Internet advantages, the web-based CSHM enables remote access, speedy data collection, retrieval, and documentation. A knowledge base was included in the design to enable online expert advice and instructions. CSHM allows the user to monitor the project performance over a certain period through analysis of the scores given to some selected parameters. Key data can be transformed into charts, curves, and tables by the database (Zhou et al., 2012).

Building Information Modelling (BIM)

The National Institute of Building Sciences NIBS (2015), defines building information modeling as follows: A Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility.

BIM enables visual assessment of construction site and identify potential hazards (Azhar*et al*., 2012; Watson, 2010). Using the BIM model to conduct visual health and safety training enables site workers to develop a better understanding of the actual site conditions (Watson, 2010). Construction workers are provided with sufficient time and information for safety planning and management before executing construction activities. With the use of sensors for data collection, the BIM can adequately reduce the likelihood of site accidents by checking the procedure of data acquisition (Druley*et al*., 2016); (Ganah & John, 2015).

3D and 4D CAD

Rwamamara *et al*. (2010) concluded that the use of 3D and 4D technologies in the early stages of construction projects allows the project team to identify potential risks. Identifying risks at an early stage minimizes cost over-runs that occur because of design changes (Azmy & Zain, 2016).
Benjaoaran and Bhokha (2009) developed a rule-based construction safety management system using the 4D CAD visualisation model. The system focused on automatically identifying fall from heights hazards since fall accidents and injuries occurred more frequently compared to other accidents on construction sites (Azmy & Zain, 2016). Data relating to activities and building's component, placement, arrangement, materials, equipment are inputted and analysed to detect any height-related hazards (Zhou *et al*., 2012). The system proposes appropriate safety requirements and measures.

Virtual Reality

Bouchlaghem, Shang, Whyte, and Ganah (2005) defined Virtual reality (VR) as a term used to describe a set of hardware and software technologies used to provide interactive, real-time, 3D computer applications. Virtual Reality is an artificial, computer-generated experience of a real-life situation orenvironment. It generates realistic imagery and hearing, making the user feel like they are experiencing the simulated reality first-hand

In construction, virtual reality has been used by the health and safety teams to review safety tie-off points and coordinating major crane picks over occupied facilities that cannot be disrupted (Haupt et al., 2019). Virtual Reality also creates a genuine health and safety work experience viable for construction health and safety training (Liand Leung, 2017). These benefits health and safety training as exercises on health and safety can be carried out in the absence of a qualified safety administer by merely simulating the training environment on a personal computer (ibid). Zhou *et al.* (2011) reiterated that traditional paper-based handouts, videotapes or slide shows hardly present electrical hazards vividly to the trainees and furthermore do not provide sufficient opportunities for trainees to interact in activities.

According to Zhou et al., (2012) some of the VR systems include;
(i) DFSP: This VR-based DFSP tool helped to identify safety hazards inherited during the building construction phase that were actually produced during the design phase. It incorporated a theory of accident causation, which lists common unsafe acts and conditions, in the investigation of safety hazards.
(ii)Virtual Construction Laboratory (VCL): is a knowledge-based VR system, developed to enable the planner to conduct virtual experiments of innovative construction technologies and processes. It has the ability to dynamically visualize the construction site environment, and enables the construction planner to identify any possible health and safety problems of the site layout before construction begins. Compared with other VR based real-field construction management systems, it provided more interactive capabilities to mock up different construction scenarios rather than mere visualization and dynamic navigation of construction site.
(iii) The CIGJS system: supports job safety analysis by applying VR technologies to generate a virtual human. CIGJS seeks to provide realistic simulations of actual work situations, contributing to job safety analyses to improve their effectiveness and usability in routine work situations, including construction work at an operational level, and to make the use of job safety analysis possible also at the design stage. Its distinguished features consist of virtual images, animation,

and 3D interactive environment. The new approach of job safety analysis combining with CIGJS permits easier, faster, and much more intuitive analysis of the hazards potentially present in each sub-task, and their effective control. It has great potentials in the field of education and training of workers on correct and safe working procedures.

Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) uses radiofrequency waves to transmit data, retrieve data and store data to identify the status of workers and objects (Yin *et al*., 2013). RFID systems are composed of an RFID tag and RFID reader, with RFID tags consisting of a small microchip and antenna. Data are stored in the tag, generally as a unique serial number. RFID tags can either be active (using battery) or passive (no battery) or have a read range of 10 to 100 meter (ibid).

In construction health and safety applications, RFID technology has been used to demonstrate real-time data gathering (Li & Leung, 2017). RFID tags have been used in simulated construction environment to track the movement of workers, equipment and materials and the resulting tag data examined to determine if a near-miss accident has occurred (Zhou *et al*., 2013). This information can further be used to prevent future occurrences (ibid). Chae (2009) designed a Collision Accident Prevention Device (CAPS) that uses RFID (Radio Frequency Identification) technology to estimate the size of the working area. The device supports accident prevention involving vehicles, heavy equipment and workers using data from the working area of each object. CAPS estimates and calculates the positional relation of heavy equipment and workers and once determined that a worker is in the restricted area of heavy equipment, a warning message is sent to the worker and concerned parties (ibid).

Methodology

Exploratory research approach was adopted by conducting a traditional literature review approach to explore the different existing emerging technologies used in construction health and safety management. Relevant research and studies on advanced technology implementation and construction health and safety were primarily obtained from multiple research databases and online-computerized search engines including Emerald Insight, Research Gate and other internet sources. A Survey to assess the extent adoption of ICT tools can improve the management of Health and Safety on construction sites in Nigeriawas carried out by administering quantitative structured questionnaires to 118 professionals (Engineers, Builders, Architects and Quantity Surveyors) in five (5) selected construction companies in South Eastern states of Nigeria. The responses from respondents were analyzed using Relative Importance Index (RII).

Data presentation and analysis

Table 1, presents the responses of professionals on the extent the adoption of ICT tools can improve health and safety management on construction site in Nigeria. Respondents were required to indicate their position on each of the identified areas ICT tools can improve health and safety management using a five (5) point Likert scale with values as follows: 5 = Strongly agree, 4 = Agree, 3 = Undecided, 2 = Disagree, 1= Strongly disagree. From the table all the areas identified had mean rating above 3.5 and RII value above 0.5, which depicts high significance of ICT tools need for improvement in all the identified areas of health and safety on construction sites.

Table 1: Responses on the extent the adoption of ICT tools can improve management of Health and Safety on construction Sites in Nigeria

Benefits of Adopting ICT tools in health and safety management on construction sites	**Frequency of Response**					**Mean Rating**	**RII**
	5	**4**	**3**	**2**	**1**		
To what extent can the ICT tools improve detection of hazards?	35	46	37	-	-	3.98	0.796
To what extent can the ICT tools improve protection of workers?	33	44	41	-	-	3.93	0.786
To what extent can the ICT tools improve control of jobsite hazards?	31	45	42	-	-	3.90	0.780
To what extent can the ICT tools improve elimination of hazards?	26	38	34	20	-	3.59	0.718
To what extent can the ICT tools improve reduction of accidents?	27	36	30	25	-	3.55	0.710
To what extent can the ICT tools improve progress visualization?	41	48	29	-	-	4.10	0.820
To what extent can the ICT tools improve early detection and prevention of accidents?	43	47	28	-	-	4.12	0.824
To what extent can the ICT tools improve real-time alerts?	47	45	26	-	-	4.18	0.836
To what extent can the ICT tools improve real-time feedback?	43	48	27	-	-	4.14	0.828
To what extent can the ICT tools improve visualization of the jobsite?	30	35	29	24	-	3.81	0.762
To what extent can the ICT tools improve emergency assessment?	31	45	42	-	-	3.91	0.782
To what extent can the ICT tools improve visualization of site logistics?	45	46	27	-	➢	4.15	0.830

Source: Researcher's field work, 2022.

Conclusion and Recommendation

The importance of efficient and effective management of construction health and safety cannot be over emphasized in the construction industry in Nigeria and beyond. This study has revealed that health and safety management can be greatly improved on the construction site by adoption of ICT

tools. It has provided construction practitioners with information on available ICT tools and gadgets that could be used to enhance health and safety management in the construction industry. Accidents can be reduced tremendously with the use of people technologies to ensure workers safety by what they wear and how they interact with their work environment. Furthermore, process technologies may be used to eliminate hazards during the design stage and with the assistance of environmental technologies used to give updated feedback on the work environment. The adoption of various safety technologies like 3D and 4D CAD, RFID, augmented reality, virtual reality, Building Information Modelling, smart sensor and wireless technology, online databases, robotics and automation have significantly increased the effectiveness of health and safety management on construction sites. Applying ICT tools in construction health and safety provides a practical means for health and safety management improvement and also enable safety personnel and practitioners to track and monitor interactions on construction sites.

Hence this paper recommends that all construction companies practicing in the industry in Nigeria must take advantage of the breakthroughs in technological advances by investing in emerging ICT tools that enhances Health and Safety performances, train staff on the use of these tools and intensify awareness on the use of these ICT tools for improving health and safety management in the industry.

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