Sub-Sahara African Academic Research Publications
March, 2022, Editions

JASOR
Journal of Advanced Science and Optimization Research
Vol. 23, No.9, ISSN 2418-9325

UTILIZATION OF ARTIFICIAL INTELLIGENCE TOOLS FOR MONITORING COMPLIANCE TO SAFETY PRACTICES ON CONSTRUCTION SITES IN ABUJA

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ABSTRACT

This study aimed at assessing the utilization of AI tools for monitoring compliance to safety practices on construction sites in Abuja. The study employed the use of quantitative research approach with the aid of questionnaire survey to obtain data from the 255 construction firms registered with the Abuja Business Directory. Out of which a sample size of 156 was gotten. Analysis of data was undertaken using Relative Index (RII). Findings from the study show that Site Sensors, Construction Wearable, Drones (UAV), Virtual Reality and Augmented Reality are the most important AI tools required for monitoring the level of compliance to safety practices on construction sites. The most significant benefit of AI tools on the level of compliance to safety practices on construction sites is "Enable management to avoid accidents and eliminate safety hazards so as to reduce the difficulty of employees as well as minimising their loss". It was therefore concluded that the application of AI tools would significantly improve compliance to safety practices on construction sites in Abuja. It was recommended that management of construction firms should invest in training their safety officers or anybody so assigned safety responsibility with the required skills, competence and confidence to implement the right technologies on the use and application of AI tools in order to be able to effectively plan and monitor site activities in a safety and health compliant manner.

Keywords: *Artificial Intelligence, Construction Site, Monitoring, Safety Practices.*

INTRODUCTION

Safety of construction workers and employees all over the world has been described as a major social responsibility and therefore it is a challenging task to ensure zero incidents at construction sites (Patil, 2017). Annually, nearly 60,000 fatal accidents happen at construction sites worldwide (Patil, 2017). This equates to approximately one fatal construction accident every 10 minutes.

According to Melzner and Bargstadt (2013), the identification of job hazards, before they actually occur, is a challenge for the construction work planner as well as for the safety and health coordinator. With the increasing level of complexity and risk of faults in the construction process, there is a high risk of occurrence of accident on construction sites. Therefore, a comprehensive review of safety issues which are often temporary during the early planning stages of a construction project is required (Melzner and Bargstadt, 2013). Due to safety problems prevalent on construction sites and the competitive nature of construction industry and its heuristic problem-solving needs, among other reasons, the development of some advanced decision-making tools have evolved; artificial intelligence (AI) is one of them (Patil, 2017).

Clavero (2018) defined AI as an amount of information that the human mind can process which is limited by time and space. However, AI captures a big quantity of data to analyze the information for trends and patterns. In essence, AI uses the machines' power to model the human natural intelligence. For example, the Machine Learning (ML) is used in AI to accomplish tasks and solve problems with superior speed and precision. Abed *et al.* (2019) noted the advantage of AI starting through using it in an early conceptual design stage, where the owner will have benefit from that. The employment of AI can effect in improving occupational safety by means of connecting the safety issues to construction planning, providing methods to manage and visualize up-to-date plans, and site status information. According to Sulvankivi (2012), the use of AI encourages other project stakeholders to share in both planning and risk assessment. There is a certain belief that AI is always useful in identifying and communicating risks to the project team because AI technology allows simulation of the real conditions of the site (Azhar, 2012).

The safety planning of construction sites is an extremely complex task. For this common practice, work preparation and safety planning are often carried out separately. Also, there are many participants in the construction process with

varying level of safety knowledge. As a result, to avoid accidents and other safety concerns on the construction sites, AI tools can be used to have a synergy where construction site workers are aware of dangers around each area on site and also monitored by the supervisors through the use of AI tools. It is on this premise therefore that this study will assess the utilization of artificial intelligence tools for monitoring compliance to safety practices on construction sites in Abuja. In order to achieve the aim of the study, the following objectives were formulated:

i. To examine the AI tools available for monitoring compliance to safety practices on construction sites in Abuja.

ii. To examine the benefits of using AI tools for monitoring compliance to safety practices on construction sites.

LITERATURE REVIEW

This section provides a detailed discussion on the main theme of the aim and objective of the study. This gives a reasonable basis for identifying the major variables required for the field work of the study.

AI Tools for Monitoring Compliance to Safety Practices in Construction

Construction industry is one of the most dangerous occupations in the world, with more occupational fatalities than any other sector in both the United States and the European Union. In 2019 Census of Fatal Occupational Injuries finds that 5,333 fatal occupational injuries in 2019 represents the largest annual number since 2007. A worker died every 99 minutes from a work-related injury in 2019. Fatalities among workers age 55 and over increased 8 percent from 1,863 in 2018 to 2,005 in 2019, which is the largest number ever recorded for this age group. Falls are one of the most common causes of fatal and non-fatal injuries among construction workers. There is a range of potential hazards at the location, from dangerous structures to moving equipment that present dangers to humans (Kim and Shin, 2017). AI is now helping to enhance overall safety on job sites. Increasingly, construction sites are equipped with cameras, IoT devices and sensors that monitor many aspects of construction operations and inform staff whenever potential safety hazards are detected. This automated process is often repeated every minute and all unsafe events are logged. It also can train image classification models to detect the character of the activity being

performed, i.e. bar bending, concreting, etc. This not only reduces liability but also can save lives and increase efficiency (Kim and Shin, 2017). The most prevalent AI tools adopted for construction works as classified according to Oke (2020) are virtual reality (VR), augmented reality (VR), construction wearable, site sensors, artificial intelligence enabled BIM, drones (UAV), autonomous heavy equipment, software and mobile app, artificial neural network and CCTV.

Benefits of Using AI Tools for Safety Compliance on Construction Sites

Artificial Intelligence (AI) based Health and Safety Monitoring solutions rely on the use of AI and technologies to monitoring construction sites. With AI programs, using data collected from the sensors such as movement detection, CCTV, heat sensors, weather sensors, it is possible to identify social distancing, hazards, safety protection equipment utilisation, personnel proximity to hazards, intrusion detection, etc. and trigger an alert before safety or health incidents occur, as well as after they have occurred, if they could not be prevented (US Government, 2020). Further reports by the US Government (2020) revealed that using AI and computer vision, movements and interactions of workers, machinery, and objects on a construction site can be assessed and tracked in real-time, against predetermined Key Performance Indicators. Such solutions, support site and safety managers in being able to better monitor and have better visibility of the work site, so they can better control the interactions and ensure health and safety for the workers. Working in construction is dangerous and it is estimated that construction workers are killed on the job five times more often than any other workers.

RESEARCH METHODOLOGY

The quantitative research approach was adopted in this study. The use of structured questionnaire was employed for data collection in order to achieve the study's objectives. The data collected were analyzed with the use of Relative Importance Index (RII). RII was employed because it is the perception of construction professionals that was sought with the questionnaire.

The population for the study is made up of construction firms registered with the Abuja Business Directory with Abuja's business address. The Abuja Business Directory as one of the Umbrella bodies of construction firms in Abuja

have about 255 construction firms registered with them. Since the study area is Abuja, then the 255 construction firms registered with the Abuja Business Directory and based in Abuja were considered for the study. The research population size is therefore 255.

The sampling frame for this study constituted professionals in charge of coordinating site activities in the various construction firms in Abuja. In order to arrive at a sample size that will serve as a representative of the entire population of construction firms in the study area, Glenn (2013) equation was used. The sample size of the study was therefore 156 based on Glenn (2013) equation.

The questionnaire (designed on a five-point Likert's Scale format) is comprised of five sections. The first section addressed issues relating to the profile of respondents. The last four sections addressed issues relating to the research objectives respectively.

In order to validate the research instrument used, a reliability test was carried out on the data collected. The result of the reliability test shows a Cronbach's Alpha of 0.840 which was very high and close to 1.000. The Cronbach's Alpha based on standardized items is 0.841 and is of a higher value and closer to 1.000. This shows that the research data are reliable and hence the research instrument is valid. The decision rule adopted for the RII is summarised in Table 1.

Table 1: Decision Rule for RII Analyses

SCALE	Cut-Off Point		Interpretation		
	RII	***MIS***	***Level of Importance***	***Level of Significance***	***Level of Effectiveness***
5	0.81 – 1.00	4.51 – 5.00	Very – Important	Very – Significant	Very -Effective
4	0.61 – 0.80	3.51 – 4.50	Important	Significant	Effective
3	0.41 – 0.60	2.51 – 3.50	Fairly – Important	Fairly – Significant	Fairly - Effective

2	0.21 – – 0.40	1.51 – – 2.50		Less – Important	Less – Significant	Less -Effective
1	0.00 – – 0.20	1.00 – – 1.50		Least – Important	Least – Significant	Least - Effective

Source: Adapted and Modified from Shittu *et al*. (2015)

The study chose 3.51-5.00 as the cut-off point for the important safety practices due to the fact that safety, being a crucial issue to the well-being of workers and success of a project, requires best practices in order to bring about improved performance. Based on the scale used (1 - 5), best safety practices should be far above average. In addition, studies from Agumba and Haupt (2014); Eze *et al.* (2016); Shittu *et al.* (2017) and Shittu *et al.* (2021) also used a cut-off point of 3.50-5.00 for the important safety practices on construction site. This therefore justifies the choice of 3.50-5.00, used in this study as the cut-off point for the important safety practices requiring the use of AI tools for proper implementation, significant benefits of AI tools and strategies significant for improving the compliance level to safety practices on construction sites.

RESULTS AND DISCUSSION

Results and Discussion on AI Tools Required For Monitoring Compliance to Safety Practices on Construction Sites in Abuja

In order to examine AI tools required for monitoring compliance to safety practices on construction sites in Abuja, Relative Importance Index was adopted. The result of the analysis is presented in Table 2.

Table 2: Results of AI Tools Required For Monitoring Compliance to Safety Practices on Construction Sites in Abuja

CODE	AI Tools	RII	RANK	DECISION
B1	Site Sensor	0.97	1st	Very Important
B2	Construction Wearable	0.92	2nd	Very Important
B3	Drones (UAV)	0.88	3rd	Very Important
B4	Virtual Reality (VR)	0.86	4th	Very Important

B5	Augmented Reality (AR)	0.83	5th	Very Important
B6	Autonomous Heavy Equipment	0.80	6th	Important
B7	CCTV	0.77	7th	Important
B8	Artificial Intelligence Enabled BIM	0.75	8th	Important
B9	Software & Mobile App.	0.72	9th	Important
B10	Artificial Neural Network	0.69	10th	Important
	Average RII	***0.82***		***Very Important***

Source: Researcher's Field Survey (2021)

Table 2 shows the 10 AI tools required for monitoring compliance to safety practices on construction sites in Abuja. The most important AI tools as revealed from result of analyses are Site Sensor, Construction Wearable, Drones (UAV), Virtual Reality and Augmented Reality with RII values of 0.97, 0.92, 0.88, 0.86 and 0.83 respectively. It was further revealed that other AI tools were ranked as important tools for monitoring compliance to safety practices on construction sites. These tools are Autonomous Heavy Equipment, CCTV, Artificial Intelligence Enabled BIM, Software & Mobile App and Artificial Neural Network with RII values of 0.80, 0.77, 0.75, 0.72 and 0.69 respectively. On the average, all the identified AI tools are required for monitoring the level of compliance to safety practices on construction sites in Abuja are very important with average RII value of 0.82. The finding here agrees with the submission of Kim (2016) which revealed that construction sites are increasingly equipped with cameras, IoT devices and sensors that monitor many aspects of construction operations and inform staff whenever potential safety hazards are detected thereby enhancing overall safety on construction sites. The finding also agree with the finding of Oke (2020) which stated that AI tools in construction are being developed at a breakneck pace. Examples include connected equipment and tools, telematics, mobile apps, autonomous heavy equipment, drones, robots, augmented and virtual reality, and 3D printed buildings which are now being deployed on construction sites across the world. AI tools have made construction sites safer and workers more efficient. It has allowed us to increase productivity, improve collaboration, and tackle more complex projects. Furthermore as reported by The US Government (2020)

revealed that AI programs, using data collected from the sensors such as movement detection, CCTV, heat sensors, weather sensors, it is possible to identify social distancing, hazards, safety protection equipment utilisation, personnel proximity to hazards, intrusion detection, etc. and trigger an alert before safety or health incidents occur, as well as after they have occurred, if they could not be prevented. It is therefore important to emphasize that for a safe and healthy construction workplace, the use of AI tools for monitoring compliance to safety rules is important.

Results and Discussion on Benefits of Using AI Tools for Safety Compliance on Construction Sites

Table 3 gives a summary of the RII results of the benefits of using AI tools for safety compliance on construction sites.

Table 3: Results of Benefits of Using AI Tools for Safety Compliance on Construction Sites

CODE	Benefits of Using AI Tools for Safety Compliance on Construction Sites	RII	RANK	DECISION
D1	Enable management to avoid accidents and eliminate H&S hazards so as to reduce the difficulty of employees as well as minimising their loss.	0.98	1st	Very Significant
D2	Increase the level of implementation of H&S measures by workers on construction sites.	0.96	2st	Very Significant
D3	Protect co-workers, employers, customers, suppliers and members of the public influence by the workplace environment.	0.95	3rd	Very Significant

D4	Reduce lots of fatalities and improve productivity by providing solutions and remedy to H&S problems and also providing workers on site with potential occurrence of existing danger on construction site.	0.95	3rd	Very Significant
D5	Avoid the direct and indirect costs of worker injuries and illnesses, and promotes a positive work environment.	0.94	4th	Very Significant
D6	Harnessing the capability to improve safety training as workers can "walk through" a job site or building increases understanding and helps prepare for the sequencing of tasks.	0.94	4th	Very Significant
D7	Create a detailed Environmental Safety and Health (ES and H) plan to be dispersed among all workers.	0.94	4th	Very Significant
D8	Intelligence of sensor-based technology helps construct an interactive management platform, which is the integration of hardware and software for data processing, significantly improving the construction site monitoring capacity and providing guarantees	0.93	5th	Very Significant

D9	Provide a high level of safety training to employees	0.92	6th	Very Significant
D10	The virtual planning of work sequencing to incorporate necessary safety equipment and measures.	0.90	7th	Very Significant
D11	Obtain timely information regarding work progress to manage workflows.	0.90	8th	Very Significant
D12	Offer opportunities to enhance communication between participants in construction projects and to enable more effective and efficient communication.	0.89	9th	Very Significant
D13	Have shaped substantially the mode of workers' interaction, business process, entertainment, learning and implementation attitude.	0.87	10th	Very Significant
D14	Capacity building in Remote Sensing (RS) and ICT is key to attain sustainability by ensuring an adequate and professional use of these techniques in the post-project period.	0.84	11th	Very Significant
D15	Providing new methods in construction and planning such as Building Information Modelling methodology and IBS technology.	0.80	12th	Significant

D16	Verification that all structures can be constructed safely and productively.	0.80	12th	Significant
D17	Integration of client, designer and contractor in design stage to eliminate adversarial nature and preventing conflict in early stage of projects which lead to mitigate the destructive risk during building process.	0.79	13th	Significant
D18	Decrease time for data processing and communicating information.	0.77	14th	Significant
D19	Avoiding the use of outdated equipment and plants during construction stages.	0.76	15th	Significant
D20	Improvement of site condition	0.75	16th	Significant
D21	Reduce the need for co-workers to be located in the same venue.	0.75	16th	Significant
D22	BIM tools allow project stakeholders to share information about sequencing, physical site topography, and clash detection; improve communication among the project stakeholders; and identify potential locations and times of hazardous and non-hazardous cons	0.74	17th	Significant
D23	Aid operational improvement through communication of construction information for	0.71	18th	Significant

	effective decision-making and coordination.			
	Average MIS	***0.78***		***Significant***

Source: Researcher's Field Survey (2021)

Table 3 revealed 23 main benefits of AI tools on the level of compliance to safety practices on construction sites. The first fourteen (14) benefits are very significant. These range from "Enable management to avoid accidents and eliminate safety hazards so as to reduce the difficulty of employees as well as minimising their loss" (RII = 0.98) to "Capacity building in Remote Sensing (RS) and ICT is key to attain sustainability by ensuring an adequate and professional use of these techniques in the post-project period" (RII = 0.84). The remaining nine benefits are also significant. These range from "Providing new methods in construction and planning such as Building Information Modelling methodology and IBS technology" (RII = 0.80) and "Aid operational improvement through communication of construction information for effective decision-making and coordination" (RII= 0.71). On the average, all the identified benefit of AI tools on the level of compliance to safety practices on construction sites are significant (average RII = 0.78). This findings as supported by The US Government (2020) submits that using AI and computer vision, movements and interactions of workers, machinery, and objects on a construction site can be assessed and tracked in real-time, against predetermined Key Performance Indicators. Such solutions, support site and safety managers in being able to better monitor and have better visibility of the work site, so they can better control the interactions and ensure health and safety for the workers. In another submission by US National Library of Medicine (2020), AI systems used in conjunction with the relevant sensors (collecting data on health and safety) help to reduce workplace hazards. AI can detect if the construction site workers are correctly wearing the required safety gear and alert them if they are missing any equipment. In addition, Wood (2016) revealed that Coutts Brothers Construction, Randolph, ME, issues their employees "V-watch" personal voltage detectors that alert the wearer to the proximity of energized materials, thereby attempting to enhance the safety of the construction workers. Such product-based innovative approaches to using technology for improving

construction safety is in response to the global necessity of improving construction safety. Therefore, safety on site is being guaranteed and construction workers are adequately protected against health hazards.

CONCLUSION AND RECOMMENDATIONS

The study revealed that AI is an idea that has been embraced in all other sectors for a very long time, therefore, urged the construction professionals to fully embrace the use of AI to enhance quality of work and to provide a safer environment for their workers. Site Sensor, Construction Wearable, Drones (UAV), Virtual Reality and Augmented Reality are the most important AI tools required for monitoring the level of compliance to safety practices on construction sites. The identified AI tools required for monitoring the level of compliance to safety practices on construction sites in Abuja are very important. The most significant benefit of AI tools on the level of compliance to safety practices on construction sites is enable management to avoid accidents and eliminate safety hazards so as to reduce the difficulty of employees as well as minimising their loss. The identified benefits of AI tools on the level of compliance to safety practices on construction sites are significant. It can therefore be concluded that the application of AI tools would significantly improve compliance to safety practices on construction sites in Abuja. There is therefore the need for construction firms to embrace the use of AI tools to monitor compliance to safety practices on site and hence improve the safety performance/practices of employees and construction firms.

In view of the findings and conclusions of this study, the following recommendations were made:

1. Most construction professionals lack adequate awareness on the use of AI tools on construction site, therefore, there is a need to organize seminars, workshops and conferences to educate the professionals on the benefits of adopting AI tools on construction sites.
2. The construction industry should collaborate with the IT industries so as to create a synergy between the both sectors. This would go a long way in strengthening the efforts between the both sectors in creating awareness of the benefits of using AI tools on construction sites.
3. The management of construction firms should invest in training their safety officers or anybody so assigned safety responsibility with the

required skills, competence and confidence to implement the right technologies on the use and application of AI tools in order to be able to effectively plan and monitor site activities in a safety and health compliant manner. This will bring about improved safety compliance of workers on site.

4. Education and training of employers and employees should be regularly used to communicate the importance of the identified safety practices mostly requiring the use of AI tools for proper implementation on construction sites to workers. This would harness the importance of safety practices to workers, therefore, ensure adequate implementation on construction sites.

The findings of this study has contributed to the body of knowledge in the built environment in various ways. The study revealed predominantly AI tools used for monitoring compliance to safety practices on construction site. The study revealed that the application of AI tools in the construction environment is important. As findings revealed that monitoring compliance to safety practices with the use of AI tools makes the construction site a safe and healthy workplace. The study shows that the utilization AI tool in the construction site will have a significant impact on the level of compliance to safety practices. The study revealed several benefits of implementing AI tools on construction site and further recommended strategies to implementing AI tools on construction sites.

In view of the limitations of this study, some areas have been suggested for further studies. Effect of construction workers' attitude on the utilization of AI tools for monitoring compliance to safety practices on construction sites. Assessment of the cost implication of adopting AI tools for monitoring safety compliance on construction sites.

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