



Appraisal of Sensor Technology as Innovative Pedagogy in Building Technology for Improving Safety Management of Building Construction Sites in Nigeria

Deborah Ahuoiza Vincent¹, Okanya Arinzechukwu Victor², Japel Onyekachi Asogwa³,
& Ujevbe Oke Benjamin⁴

Department of Industrial Technical Education

Faculty of Vocational and Technical Education

University of Nigeria, Nsukka, Nigeria

ABSTRACT

The study appraised sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites in Enugu State, Nigeria. Two purposes and two research questions guided the study. The design was a descriptive survey and the instrument used was a structured questionnaire. The population for the study was 65, comprising of 42 Construction managers and 23 Site supervisors from registered construction company residents in Enugu state. Three experts face validated the Instrument and the Cronbach alpha reliability method was used to determine the internal consistency of the questionnaire items while 0.89 was obtained. The data collected were analyzed using mean and standard deviation. The study found 13 sensor technologies that can be used for safety management in construction sites in building technology. The findings of the study also revealed that sensor technology is an innovative pedagogy for improving safety management in construction sites. The study, therefore, recommended, among others, that construction managers should adopt the use of sensor technology for safety management in building construction sites, all construction workers should be trained on the use of sensor technology and the curriculum of building technology should be reviewed to accommodate the new innovation.

Keywords: Sensor Technology, Safety Management, Building Construction Site, Building Technology.

1. INTRODUCTION

Building Technology is a central field in the construction industry. It is the technologies used in the process of building structures. Chukwu, D.U.et. al., described building technology as the use of all-embracing technological skills and capacity to manage machineries, products and man in order to carry out building task efficiently and resourcefully [1]. In the context of this study, building technology refers to the procedures, skills practices, technical methods, tools and materials used for the erection, refurbishment or maintenance of buildings. Building technology is dynamic and as a result, it is experiencing a pattern shift today from old concept of safety management to new concept of safety management for safer environment for both human and materials resources. The old concept of safety management practices in building technology includes formulation of safety policy, emergency preparedness, incident investigation, carrying out safety inspections, hazard analysis, hazard control, organizing health and safety training programmes, organization of safety committees, risk management and control. However, one of the new concept for safety management is the application of sensor technology. Sensor technology has developed quickly and are being utilized in different sectors such automotive, medical and healthcare, aviation, manufacturing, banking, agriculture, marine and oil sectors. Similarly, the building industry is not left behind. [2] reported that mishaps arising from building construction work in Nigeria construction sites is becoming a serious challenge as a result of poor safety management and non-compliance to safety management practices, leading to incurring excess cost, injuries to workers, project disruption and massive loss of life. Therefore, innovative technology such as sensor technology should better be incorporated into building technology pedagogy to enhance safety management in building construction sites.

Construction site is often used substitutable with building site. There is sometimes misconception in terminologies of construction site as a 'building site' although this tends to indicate that buildings are being constructed, though the term 'construction site' can denote all types of works, including road construction, sewer construction, landscaping or other construction works. Building construction site in the context of this study, is an area or piece of land where construction works are being carried out. Building construction site is prone to risks because of the operational activities carried out on the site. [3] and

[4] claimed that the number and magnitude of accidents occurring and recorded in construction sites in Nigeria underscore low level of safety practices. It is therefore required that safety management be strictly practiced and obeyed in building construction sites to avert fatalities. Safety management of workers within the building construction sites demand utmost attention before construction work starts and as soon as the first phase of construction begins. Apparently, in building construction sites, there is limitation to the capacity of safety managers through physical monitoring on the site. [5] affirmed that physical monitoring on site may cause some difficulty with regard to the need of the safety manager to be preemptive and continuous on-site monitoring for the precise identification of construction safety issues both on workers and machines to be used. Mishaps arising from construction work in construction sites are quite alarming. It is therefore necessary to integrate innovative pedagogy such as sensor technology for safety management.

Safety management is a vital element in building technology. It is essential to manage the safety of workers, materials and the environment where building construction work is being carried out. [6] described safety management as the practice used to identify health and safety risks and implement actions to lessen the possibility of risk occurring and to lessen or eliminate the potential consequences of identified project health and safety risks. This implies that safety management takes account of all risks and accidents that may be expected to put employees at risk and minimize such risks. It is thus important to identify appropriate safety actions and strategies to accommodate potential serious health and safety problems that may occur in building construction sites[7]. Construction work is dynamic in nature and consists of various tedious work such as building construction, industrial management, structural mechanics and other related work and often times difficult to conduct safety management suitably. [8] affirmed that the complex environment of construction sites in daily activities often lead to difficulty in conducting safety inspections by safety managers. Hence, sensor technology can be used to securely monitor and control site conditions based on safety standards. For building technology work not to be impeded, it is pertinent to safeguard workers health. Sensor technology could hold a great potential in enhancing safety management and handling hazards in building construction sites. Hence, the need for adoption of sensor technology.

Sensor technology is driven by technological evolution. Recently, the rise of the Internet of Things (IoT) and its associated technologies such as sensor technology has enhanced interest in the safety management of construction work in building technology. [9] described sensor technology as a technology that uses sensors to obtain data by sensing the physical such as bodily functions, chemical such as natural environment or biotic property and convert them into a readable signal. Sensor technology is of utmost intelligence level as it helps construct an interactive safety management platform within the construction site which is a combination of hardware and software for data processing [10]. The inputs of sensor technology are physical observations with a corresponding output so as to improve safety in the workplace [11]. Sensor technology applied to construction work in construction sites include; location sensing technology, vision sensing technology and wireless sensor networks among others. The use of sensor technology has proactively addressed human hazards, environmental hazards and mechanical hazards.

According to the [12] injuries, hazards and fatalities in construction sites have taken account of large number of construction workers deaths. These injuries, hazards and deaths could have been averted by equipping the workers with sensor technologies such as wearable sensors. Sensor technology encompasses all the new technologies that are applied to workplace safety including mobile apps, wearables, machine sensors, cloud-based software, predictive analytics, 3D printing, robotics, real-time employee monitoring and tracking and Personal Protective Equipment tracking with embedded sensors among others. [13] reported that sensor technologies are put to use within the construction site and are important to the safety of workers during construction work. The authors further stated that sensor technology provide preventive measures to escape unexpected situation or taking strict cognizance of situations that may lead to unfriendly occurrence. Therefore, it becomes necessary to adopt the use of sensor technology for greater efficiency in safety management in building construction sites. The study therefore, aimed at appraising sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites in Enugu state.

1.1 Statement of the Problem

Despite the existing safety management pedagogy in building technology, mishaps continue to occur on a daily basis in building construction sites and the fatalities rate are becoming a serious challenge. Building technology pedagogy on safety management has adopted several methods such as traditional means which include safety policy and organization, safety inspections, accident or incident investigation, safety and health training programmes, survey or hazard analysis, hazard control by using personal protective equipment (PPE), emergency preparedness, organization of safety committees, risk management and control in construction sites. Hazardous events continuously occur in building construction sites resulting to injuries of workers, project interruption, and loss of lives.

Also, monitoring the safety conditions of workers through the traditional methods of safety management is becoming more challenging due to the increase in complexity of building construction work and the number of projects occurring by the day. Safety management has not been properly investigated, and unfortunately, individual’s safety performance remains poorly understood. The safety management practices adopted to enhance workers safety have continued to threaten worker’s health and lives and have become a significant problem especially in building construction sites. Consequently, there is still a wide gap in construction safety management practices of building construction site and there are more casualties recorded as a result of inefficient safety management practices.

Clearly, there is a need for the building construction industry to improve the health and safety of workers and even the safety of materials and the environmental conditions through the application of sensor technology which can make use of sensing devices to monitor health conditions of workers, environmental conditions and the functional ability of machines which can be dangerous to workers if faulty or not properly operated before or during the construction stage. This study therefore is designed to appraise sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites in Enugu state.

2. PURPOSE OF THE STUDY

The general purpose of this study is to appraised sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites in Enugu state. Specifically, the study sought to:

1. Identify the sensor technologies that can be used as innovative pedagogy in building technology for improving safety management of building construction sites.
2. Evaluate how effective is the use of sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites.

3. METHODOLOGY

The study adopted a descriptive research design. The area of the study was Enugu State. The population for the study was 65, comprising of 42 Construction managers and 23 Site supervisors from registered construction company resident in Enugu state. The entire population was used because the size was manageable. The instrument used was a structured questionnaire with a four-point rating scale of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD) with values of 4, 3, 2, and 1 respectively. The questionnaire consists of 32 items developed from the reviewed literature. The instruments were face validated by three experts. Two experts from the Department of Industrial Technical Education, University of Nigeria, Nsukka and one expert from Roboconsult limited, Nsukka, Enugu state. The expert made some inputs that were integrated to improve the final copy of the instrument. The Cronbach alpha reliability method was used to determine the internal consistency of the questionnaire items. Ten copies of the questionnaire were administered on 5 Construction managers and 5 Site supervisors in registered building construction industry in Anambra State. Their responses were analyzed using Statistical Package for Social Sciences (SPSS) version 26.0 and an overall coefficient of 0.89 was obtained. Data was collected by the researcher with the help of two research assistants with 97% returned rate. The data collected were analyzed using mean and standard deviation to answer the research questions. All computations were done using Statistical Package for Social Sciences (SPSS) version 26.0.

Results

The results of the data analysis were presented in the tables according to research questions.

3.1 Research Question 1

What are the sensor technologies that can be used as innovative pedagogy in building technology for improving safety management of building construction sites?

Data for answering research question was presented in Table 1.

Table 1: Mean responses of Construction managers and Site supervisors on the sensor technologies that can be used as innovative pedagogy in building technology for improving safety management of building construction sites.

S/N	Item Statements	X	SD	Decision
1	Temperature sensor device for measuring the amount of heat energy or coldness of an objects or environment or conditions of workers.	3.71	0.63	A
2	Displacement sensor device for measuring the distance between an object and the reference position i.e. building inclination control and building subsidence monitoring.	3.59	0.58	A

3	Light sensor device for non-destructive examination of structural components such as concrete constructions, pile foundations, and welding seams in steel structures.	3.56	0.55	A
4	Gas sensor device for monitoring changes in air quality or detect the presence of gases, or toxic or combustible gases in the atmosphere or an area in building construction sites.	3.74	0.49	A
5	Fire sensor device for detecting the presence of flames in the air or an area in building construction sites.	3.53	0.72	A
6	Optical fiber sensor for sensing insensitive conditions such as noise, extreme heat, high level of vibration, wet and unstable environments such as deformations, cracks of structures in building construction sites.	3.62	0.52	A
7	Laser sensor device for measuring physical parameters such as length, speed and flow i.e. for grading, site preparation and excavation measurement such as determining site's area or verifying the percent grade of a slope if it can be efficient, safe and accurately done.	3.50	0.73	A
8	Distance sensor device for distance measurement i.e. to detect objects proximity in building construction sites.	3.48	0.69	A
9	Biometrics sensor device for monitoring the people (workers) on the site i.e. for monitoring workers heart rate, posture, body temperature and repetitive motions of the workers in building construction site.	3.51	0.63	A
10	Humidity sensor device for measuring the amount of water vapour in the atmosphere as too much moisture in the air causes condensation, which can cause some machinery to corrode.	3.74	0.60	A
11	Pressure sensor device for monitoring structural loads in building especially in testing end bearing capacity of pile foundations.	3.58	0.65	A
13	Motion sensor device used for sensing physical movement of an object or person and basically used for security purposes or for checking intruders in building construction sites.	3.56	0.63	A

Note: X = Mean; SD = Standard Deviation; Strongly Agreed (SA) = 4; Agreed (A) = 3; Disagreed (D)= 2; Strongly Disagreed (SD)= 1.

The mean ratings of the responses of construction managers and site supervisors in Table 1 ranged from 3.74 to 3.48 which are all greater than the cut-off point value of 2.50 on a 4-point rating scale. This implied that the thirteen identified items in the table are agreed upon by the construction managers and site supervisors to be sensor technologies that can be used as innovative pedagogy in building technology for improving safety management of building construction sites. The standard deviation values of the thirteen items in the table ranged from 0.73 to 0.49 which indicated that the respondents are not only close to one another, but are also close to the mean.

3.2 Research Question 2

How effective is the use of sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites?

Data for answering research question was presented in Table 2.

Table 2: Mean responses of Construction managers and Site supervisors on how effective is the use of sensor technology as innovative pedagogy in building technology for improving safety management of building construction sites.

S/N	Item Statements	X	SD	Decision
1	Sensor technology can effectively monitor site operations such as excavation work, scaffolding work, crane operations, hoisting operations, forklift operations, electrical operations and welding work	3.71	0.83	A
2	Sensor technology can effectively monitor weather conditions such as high or low temperature, rainstorm, windstorm, dust or fog, hot and dry weather which may be harmful to some construction work or procedure.	3.54	0.74	A
3	Sensor technology can effectively monitor the psychological conditions of workers such as stress level, emotions, anxiety, pressure and tension that may cause workers to act unsafely in certain conditions.	3.61	0.76	A
4	Sensor technology can effectively detect unsafe behaviour of workers such as alcohol intake and smoking which are risk factors that can lead to hazardous work conditions.	3.75	0.77	A
5	Sensor technology can effectively detect hazardous material release in building construction sites such as chemicals or solvents.	3.54	0.69	A

6	Sensor technology can effectively improve facility management in the construction sites i.e. equipment and materials.	3.60	0.70	A
7	Sensor technology can effectively detect explosive substances within the site environment such as fire and gas.	3.22	0.83	A
8	Sensor technology can effectively detect hazards in dangerous zones in building construction sites.	3.39	0.93	A
9	Sensor technology can effectively detect the interference of any physical intrusion within the building construction site.	3.71	0.83	A
10	Sensor technology can effectively enhance safety and security of workers and the environment.	3.30	0.74	A
11	Sensor technology can effectively enhance equipment and material management.	3.45	0.66	A
12	Sensor technology can effectively detect workers inappropriate work procedure.	3.40	0.72	A
13	Sensor technology can effectively detect malfunction in mechanical devices used in building construction sites.	3.69	0.71	A
14	Sensor technology can effectively detect improper machining guard.	3.45	0.87	A
15	Sensor technology can effectively detect hazardous arrangement of mechanical devices which can be harmful to workers in building construction sites.	3.58	0.92	A
16	Sensor technology can effectively detect deficiency in plant, equipment, tools and general work environment in building construction sites.	3.54	0.70	A
17	Sensor technology can effectively track objects within the site environments i.e. misplaced item.	3.48	0.79	A
18	Sensor technology can effectively detect unsafe mechanical design or construction.	3.57	0.59	A
19	Sensor technology can effectively monitor safety of workers in confined spaces such as compressed air environment i.e. sewers and tunnels.	3.60	0.51	A

Note: X = Mean; SD = Standard Deviation; Strongly Agreed (SA) = 4; Agreed (A) = 3; Disagreed (D)= 2; Strongly Disagreed (SD)= 1.

The mean ratings of the responses of construction managers and site supervisors in Table 2 ranged from 3.75 to 3.22 which are all greater than the cut-off point value of 2.50 on a 4-point rating scale. This implied that the nineteen identified items in the table are agreed upon by the construction managers and site supervisors to be how effective the use of sensor technology can be used as innovative pedagogy in building technology for improving safety management of building construction sites The standard deviation values of the nineteen items in the table ranged from 0.93 to 0.51 which indicated that the respondents are not only close to one another, but are also close to the mean.

4. DISCUSSION

The findings of the study revealed that sensor technology devices such as temperature sensor, pressure sensor, displacement sensor, gas sensor, fire sensor, optical sensor, distance sensor, biometrics sensor, humidity sensor, pressure sensor and motion sensor can be used for improving safety management in building construction sites. The findings of the study are in agreement with the findings of [14] who identified pressure sensor device as a useful device for structural load measurement. Temperature sensor device as a useful device for monitoring shrinkage crack in mass concrete and concrete curing in building construction; displacement sensor device for building inclination monitoring, building subsidence monitoring, geological prediction and geological hazard pre-warning; light sensor device for monitoring of structural components and optical fiber sensor devices for monitoring strains, deformations and cracks in structures.

The findings of the study also identified how effective sensor technology can be used as innovative pedagogy in building technology for improving safety management of building construction sites to include monitoring of site operations, monitoring of weather conditions, monitoring of workers psychological conditions of workers, detect hazardous material release in building construction sites, detect the interference of any physical intrusion, detect malfunctions in machines and other related items. The finding of the study is in consonance with that of [15] who observed that sensor technologies can be used to monitor the health and safety of worker and also monitor materials and equipment in building construction sites. The authors further noted that sensor technology can be used for site operation management such as concrete processing, excavation process, detection of potential hazards in heavy equipment and vehicles coming in and out of the construction sites, detection of highly prone dangerous areas, materials control and tracking construction items in construction job sites. Similarly, [16] noted that sensor technology is capable of improving safety management and practices in construction sites through physiological monitoring, environmental sensing, proximity detection and location tracking.

5. CONCLUSION

Analysis of data for this study have shown that sensor technology provide data on the humidity level, temperature level, pressure level, motion, light changes, vibration level, body posture of workers, heart rate of workers, gas/fire presence, noise level, distance level and physical parameters among others which will go a long way to limit the possible hazards facing construction workers in building construction sites. Consequently, if sensor technology is adopted for safety management in building construction sites in Enugu state and in Nigeria at large, building construction sites will be as safe as possible as sensor technologies proactively address hazards and environmental risks. Potential injuries to workers, accidents due to heavy operating equipment and tools, and fatalities will drastically reduce in building construction sites.

Finally, the inadequacies in traditional safety management practices would be met and the require efforts towards advancement in safety management pedagogy in building technology will be achieved thus, making the building construction sites a safe site for all workers in the construction industry.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. In improving safety management in building construction sites, building construction managers, site supervisors, builders and all engineers involved in building construction work should adopt the use of sensor technology.
2. Provision should be made by clients and contractors in training of all construction workers on the use of sensor technology.
3. The curriculum of building technology should be reviewed to accommodate the new innovation.
4. The government, building owners and contractors should increase the allocation of money to safety management to enhance safety in building construction sites.
5. Public awareness should be created on the use of sensor technology for safety management in building construction sites.

REFERENCES

1. Chukwu, D.U., Ojo. S.A. & Osinem, E.C. (2017). Aspects of Collaborative Learning Model for Developing 21st-Century Skills in Building Technology Students. *Journal of Technical Vocational Education, Training and Research*, 2.
2. Waziri, B. S., Adama-Hamma, M. & Kadai, B. (2015). Exploring Health and Safety Practices on Some Nigerian Construction Sites. *6th West Africa Built Environment Research (WABER) Conference*, 10-12 August, 2015 at Accra Ghana, Vol 1, 491-502.
3. Idubor, E. E. & Oisamoje, M.D. (2013). An Exploration of Health and Safety Management Issues in Nigeria's Effort to Industrialize. *European Scientific Journal*. 9 (12). 92-104.
4. Umeokafor, N., Umeadi. B., Jones, K. & Igwegbe, O. (2014). Compliance with Occupational Safety and Health Regulations in Nigeria's Public Regulatory Entity: A Call for Attention. *International Journal of Scientific and Research Publications*. 4(5), 1-3
5. Yang, K., Ahn, C., Vuran, M. & Aria, S. (2016). Semi-Supervised Near-miss Fall Detection for Ironworkers with a Wearable Inertial Measurement Unit. *Journal of Automation in Construction*, 68, 194-202.
6. Saeed, Y. S. (2017). Safety Management in Construction Projects. *Journal of University of Duhok*. 20 (1), 546-560.
7. Nwakile, T.C., Eze, C.C & Okanya, A.V (2017). Sanitation practices on Students Health: A Case Study of Students of Vocational and Technical Education in the University of Nigeria, Nsukka. *International Journal of Multidisciplinary and Current Research*, 5, <http://ijmcr.com/sanitation-practices-on-students-health-a-case-study-of-students-of-vocational-and-technical-education-in-the-university-of-nigeria-nsukka/>
8. Park, J., Cho, Y., & Martinez, D. (2016). A BIM and UWB Integrated Mobile Robot Navigation System for Indoor Position Tracking Applications. *Journal of Construction Engineering Project Management*. 6, 30-39.
9. Yokogawa Electric Corporation YEC. (2020). Definition of Sensor and Sensing Technology. Retrieved online from <https://www.yokogawa.com/special/sensing-technology/definition>. 25/06/2021.
10. Montaser, A. & Moselhi, O. (2014). Truck+ For Earthmoving Operations. *Journal of Information in Construction ITcon* 19, 412-433. Retrieved online from <http://www.icon.org/2014/25>. 6/6/2020.
11. Census of Fatal Occupational Injuries CFOI. (2018). Census of Fatal Occupational Injuries: Overview. Retrieved online from <https://www.bls.gov/iif/oshcfoi1.html12018>. 26/06/2021
12. Zhang, M., Cao, T. & Zhao, X. (2017). Applying Sensor-Based Technology to Improve Construction Safety Management. *Multidisciplinary Digital Publishing Institute*, 17(2), 1-24. Retrieved from www.mdpi.com/journal/sensors.
13. Tahir, Namadi, Mohammed & Yahaya (2015). Improving Health and Safety in the Nigerian Construction Sites Using Radio Frequency Identification (RFID), Proceedings of The Inter-Disciplinary Academic Conference on Uncommon Development, 4 (3) Jan 15-16, 2015 – University of Jos Multi-purpose Hall, Main Campus, Jos, Plateau State.

14. Awolusi, I. G. (2017). Active Construction Safety Leading Indicator Data Collection and Evaluation. (Unpublished Doctoral Dissertation), Department of Civil, Construction, and Environmental Engineering, University of Alabama.
15. Ahmed, S. Yarima, M, Yahaya I. M. &Mahmud, A. (2015). Improving Health and Safety in the Nigerian Construction Sites Using Radio Frequency Identification (RFID), *Proceedings of The Inter-Disciplinary Academic Conference on Uncommon Development*, 4 (3) Jan 15-16, 2015 – University of Jos Multi-purpose Hall, Main Campus, Jos, Plateau State.
16. Ibrahim, M. &Moselhi, O. (2014). Wireless Sensor Networks Configurations for Applications in Construction, *Procedia Engineering*, 85, 260-273. doi: 10.1016/j.proeng.2014.10.551