Global Journal of Information Technology: Emerging Technologies

Volume 14, Issue 2, (2024) 79-88

www.gjit.eu

Perception of building technology lecturers on the adoption of wearable technologies for worker safety in Nigeria's building construction sector

Godwin Keres. O. Okereke [a1], University of Nigeria Nsukka, Obukpa Rd, Nsukka 410105, Enugu, Nigeria. godwin.okereke@unn.edu.ng, https://orcid.org/0009-0001-0833-7797
Arinzechukwu Okanya [b*], University of Nigeria Nsukka, Obukpa Rd, Nsukka 410105, Enugu, Nigeria. okanya@unn.edu.ng, https://orcid.org/0000-0003-4546-3490
Joy Okereke [c], Enugu State University of Science & Technology, 01660. Agbani, Enugu, Nigeria. https://orcid.org/0000-0003-1808-2174
Lawal Umar [d], Federal College of Education Technical Bichi, 66G8+Q62 Eleven road Sabon layi kanti, Bichi 703101, Kano, Nigeria.
Anthony Yakubu [e], Kaduna State College of Education Gidan-Waya, 1024, Kafanchan, Nigeria. yakubuanthony2016@gmail.com,
Cosmas Ezugwu [f], Enugu State College of Education (Technical), Abakaliki Rd, GRA, Enugu 400102, Enugu, Nigeria. ezugwucosmas@gmail.com,
Ebiegberi Kontei [g], University of Nigeria Nsukka, Obukpa Rd, Nsukka 410105, Enugu, Nigeria.

Suggested Citation:
Okereke, G.K.O., Okanya, A., Okereke, J., Umar, L., Yakubu, A., Ezugwu, C. & Kontei, E. (2024). Perception of building technology lecturers on the adoption of wearable technologies for worker safety in Nigeria's building construction sector. *Global Journal of Information Technology: Emerging Technologies, 14*(2), 79-88 https://doi.org/10.18844/gjit.v14i2.9591

Received from; March 8, 2024, revised from; August 21, 2024, and accepted from September 21.
Selection and peer review under the responsibility of Assoc. Prof. Dr. Ezgi Pelin YILDIZ, Kafkas University, Turkey

iThenticate Similarity Rate: 2%

Abstract

This study explored building technology lecturers' perceptions of wearable technologies to improve safety in Nigeria's construction sector. With safety as a pressing industry concern, the research highlights the slow adoption of wearable devices, emphasizing their importance for accident prevention. Identifying this gap, the study aimed to assess the perceptions of these professionals to guide policy and implementation strategies. Using a survey design, data were collected from a manageable population of 62 respondents, comprising building technology lecturers and laboratory technologists across four universities. The primary data collection tool was a validated questionnaire utilizing a 5-point Likert scale. The analysis employed mean and standard deviation for research questions and t-tests for hypotheses, with findings indicating a low perception of the implementation of wearable technologies. The study recommends collaboration among industry professionals and stricter enforcement of regulations to encourage the adoption of safety-enhancing technologies.

Keywords: Building construction; construction workers; wearable technologies; worker safety.

* ADDRESS FOR CORRESPONDENCE: Godwin Keres. O. Okereke, University of Nigeria Nsukka, Obukpa Rd, Nsukka 410105, Enugu, Nigeria.
E-mail address: godwin.okereke@unn.edu.ng

1. INTRODUCTION

Building construction is a physically demanding, risky, and unhealthy operation that constantly exposes workers to a variety of workplace hazards and accidents. Accidents have a huge adverse impact on construction projects, such as loss of human lives, increased medical expenses, worker's mental illness, loss of time, productivity loss, reduced morale, and conflict with workers (Balkhyour et al., 2019). Because of the presence of heavy gear, high work zones, and possible exposure to different dangers such as falls, equipment accidents, toxic chemicals, and structure collapses, construction sites are inherently hazardous settings (Abina et al., 2023). Safety for construction workers cannot be stressed. Therefore, construction worker safety is a top priority in the construction sector. Construction safety refers to the procedures, protocols, and practices put in place to ensure the safety and physical well-being of construction workers (Dong et al., 2018; Zhao et al., 2024; Kim et al., 2024). Nnaji et al., (2021) defined construction safety as the consequence of proper equipment use, worker safety, frequent site inspections, and risk assessments. Compliance with regional safety and health requirements is a critical component of construction safety (Abdalfatah et al., 2023).

In many nations, ensuring worker safety is not just a moral imperative, but also a legal necessity. Construction businesses must offer a safe working environment and follow safety regulations and guidelines to avoid accidents, injuries, and fatalities (Lee et al., 2023). Traditional safety measures, while effective to some extent, often fall short of addressing the dynamic and unpredictable nature of construction work. This is where Abuwarda et al., (2022) stated that wearable technology comes into play, offering real-time monitoring, data analytics, and proactive safety measures to mitigate risks and improve overall safety outcomes.

Wearable technology refers to devices that are worn on the body, and integrated into clothing or accessories, to monitor various physiological and environmental parameters during construction works (Dang et al., 2022). Sadhu et al., (2023) stated that wearable technologies are electronic devices designed to be worn on the body and equipped with sensors, microprocessors, and connectivity features to enhance worker safety. In a nutshell, wearable tech plays a crucial role in enhancing worker safety and well-being because it can help construction workers do their jobs safely. Wearable devices and technologies can warn building construction managers when workers are close to a danger zone on the job site and they can come in a variety of options. Some can even track the workers' health while also tracking productivity (Okoye, 2018). According to Pillai et al., (2020), some top safety wearable devices and technologies include: watches, smart boots, augmented reality (AR) glasses, and smart gloves. Other popular examples of wearable technologies in construction projects include wearable helmets, smart boots, and exoskeletons. The adoption and utilizing this unique device on construction sites, especially those working in high-risk environments can enhance construction safety through: real-time monitoring of construction activities on site, environmental awareness, better communication and training fall detection and prevention, and improving workplace efficiency.

Wearable technologies make it easy to monitor the real-time vital signs of workers, such as heart rate, body temperature, and fatigue level (Oke et al., 2022). Wearable heart monitoring devices, such as smart watches, can help supervisors on construction sites avoid accidents and injuries by analyzing real-time data. The supervisors can take immediate action after learning about the health issues of the site workers. The use of smartwatches for construction workers improves both productivity and safety at work. Wearable technologies can also foster the environmental awareness of construction workers.

Wearable devices that are equipped with augmented reality (AR), like smart glasses and smart helmets, help workers get information about their surroundings (Dithebe et al., 2019). It helps to overlay digital information into the real-time world and enhance productivity. The construction site often exposes workers to hazardous conditions like poor air quality, excessive noise, temperature, and extreme height or depth. Wearable technology allows employees to receive alerts in real-time and take necessary action. It enhances situational alertness and

prevents accidents and mistakes. Wearable technologies and devices can also enhance better communication of workers on site.

By employing advanced construction technology, workers can easily communicate with fellow workers and supervisors. Sometimes the noisy environment or unusual construction site can obstruct workers from following the right instructions. It slows down the construction work and increases the chances of accidents. By getting equipped with smart helmets and glasses, workers get alerts and clear instructions as per their tasks and locations (Okpala et al., 2019). The built-in communication technologies in wearable equipment allow workers to have hands-free communication and enable them to stay connected without distraction. Nnaji et al., (2021), stressed that wearable technologies can help in fall detection and prevention.

Wearable technology, such as motion sensors and accelerometers, detects sudden changes in body movement and prevents sudden falls. These advanced biometric sensors give workers an alert and save them from falling. It is worth measuring the health conditions and vital signs of the workers, like fatigue and heat stress. These devices have the potential to collect worker data in outdoor and indoor environments. Occupying this construction equipment produces a secure environment for the workplace. Getting immediate alerts to do an immediate response to save lives on construction sites which in turn promotes workplace efficiency.

Wearable technology increases a worker's efficiency in a variety of ways. The simplest one is to help them perform their tasks. For example, exoskeletons will increase workers' strength and stamina, enabling them to do more work in less time. Additionally, exoskeletons can monitor the worker's posture and movement, notifying them if they twist or bend in a harmful way. Another way wearable devices and technologies can improve onsite efficiency is through streamlining data collection. For example, when supervisors perform manual headcounts or safety checks, they are prone to making mistakes, and these tasks are often time-consuming. Not only can wearable devices do the same activities almost instantaneously, taking up very little time, but their margin of error is also minuscule (Ercan, & Timur, 2020). Should wearable devices be integrated with other technological solutions within the construction industry, this could dramatically boost productivity. For instance, smartphones are already used in tandem with construction management applications to generate reports on the spot and wearable devices could perform a similar role.

The construction sector in Nigeria is lately considering technological innovations as an alternative means of addressing its workplace hazards and accident challenges. The construction management and engineering literature is rife with the need to train and educate construction workers on using digital technologies to solve workplace hazards and challenges. One of these technologies is wearable safety devices and technologies. Wearable devices and technologies have proven to be effective in preventing musculoskeletal disorders, preventing falls, assessing physical workload and fatigue, assessing hazard identification skills, and monitoring workers' mental status. Despite the associated benefits, the technology is still new, particularly to construction organizations in developing countries in Nigeria. Therefore, challenges to its adoption and implementation by construction organizations are inevitable. This study aims to investigate the perception of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in Nigeria's building construction sector.

1.1. Purpose of study

The main purpose of the study was to ascertain the perception of building technology lecturers on the adoption of wearable technologies for worker safety in Nigeria's building construction sector. Specifically, the study ascertained:

1. The emerging wearable technologies that can be used in building construction.

2. The perception of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector.
3. The challenges to the adoption of wearable technologies in the Nigerian building construction sector.

In line with the researchers' objectives, the following questions were raised:

1. What are the emerging wearable technologies that can be used in building construction?
2. What are the perceptions of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector?
3. What are the challenges to the adoption of wearable technologies in the Nigerian building construction sector?

The hypothesis for the study is;

There is no significant difference in the mean responses of building technology lecturers and building laboratory technologists on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector.

2. METHOD AND MATERIALS

2.1. Participants

The study adopted the survey research design. The study was carried out in four universities in South East Nigeria. They include the University of Nigeria, Nsukka (UNN), Michael Okpara University Umudike, Nnamdi Azikiwe University (NAU), and Enugu State University of Technology (ESUT). The population for this study is 62 respondents, which comprised 24 building technology lecturers and 38 building laboratory technologists from the four universities. The entire population was used as a sample for the study due to the manageable size of the population.

2.2. Data collection instrument

A structured questionnaire was the instrument for data collection. The items used a 5-point Likert scale of strongly agreed, agreed, undecided, disagreed, and highly disagreed, which were assigned numerical values of 5, 4, 3, 2, and 1 respectively. The instrument was subjected to face and content validation by one lecturer from the Department of Industrial Technical Education, UNN, and one lecturer from the Department of Building Technology, in ESUT and NAU respectively. This was done to attest to the appropriateness of the instrument in measuring what it is intended to measure. The instrument was trial tested on 10 building technology lecturers and 10 building laboratory technologists from the Department of Vocational and Technical Education at Benue State University. This yielded a reliability coefficient of 0.73 using the Cronbach Alpha formula. Sixty-two (62) copies of the questionnaires were distributed to the respondents from the four tertiary institutions in the study. However, only 60 copies of the questionnaires were filled and returned yielding a 98% return rate. The data were collected by administering the questionnaire directly to the respondents by the researchers with the aid of two research assistants.

2.3. Data analysis

The data collected from this study were analyzed using mean and standard deviation in answering the research questions. Any item with a mean value of 3.50 and above was regarded as agreed while any item with a mean below 3.50 was regarded as not agreed. The t-test was used to test the hypotheses at a probability level of 0.05 level of significance.

3. RESULTS

Table 1 showed all 10 items had their mean values ranging from 3.58 to 4.57 which were above the cutoff point of 3.50. This is an indication that the respondents accepted the items as emerging wearable technologies that can be used in building construction.

Table 1

Mean and Standard Deviation of Respondents on the emerging wearable technologies that can be used in building construction **N=60**

S/N	Item Description	X	SD	Remark
1	Smart helmet	3.58	1.09	Agreed
2	Smart vests, Safety Vests, and Jackets	3.54	0.74	Agreed
3	Smartwatch	4.20	0.79	Agreed
4	Exoskeletons	4.07	0.87	Agreed
5	Smart Glasses	3.57	0.55	Agreed
6	Hearing Protection Devices	4.51	0.55	Agreed
7	Smart Shoes, Smart Boots and Insoles	3.57	0.55	Agreed
8	Smart Hard Hats	3.55	0.66	Agreed
9	Smart Wristband	4.14	0.51	Agreed
10	Biometric Monitoring Devices:	4.44	0.65	Agreed
	Grand Total	**4.34**	0.17	Agreed

Table 1 also showed that the standard deviations (SD) of the items ranged between 0.55 - 1.09 which indicated that the responses of the respondents were close to each other and the mean.

Table 2

Mean and Standard Deviation of Respondents on the perceptions of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction Sector

N=60

S/N	Item Description	X	SD	Remark
1	Building construction managers often do not ensure the usage of Smart helmets by construction workers onsite.	3.96	0.60	Agreed
2	Building construction managers often do not ensure the usage of smart vests, safety vests, and jackets by construction workers onsite.	3.56	0.74	Agreed
3	Building construction managers often do not ensure the usage of Smart-watch by construction workers onsite.	3.63	0.67	Agreed
4	Building construction managers often do not ensure the usage of exoskeletons by construction workers onsite.	3.68	0.51	Agreed
5	Building construction managers often do not ensure the usage of smart glasses by construction workers onsite.	3.55	0.67	Agreed
6	Building construction managers often do not ensure the usage of hearing protection devices by construction workers onsite.	3.69	0.66	Agreed
7	Building construction managers often do not ensure the usage of smart shoes, smart boots, and insoles by construction workers onsite.	3.63	0.67	Agreed
8	Building construction managers often do not ensure the usage of smart hard hats by construction workers onsite.	3.68	0.51	Agreed
9	Building construction managers often do not ensure the usage of smart wristbands by construction workers onsite.	3.55	0.67	Agreed
10	Building construction managers often do not ensure the usage of biometric monitoring devices by construction workers onsite.	3.59	0.66	Agreed
	Grand Total	**3.88**	**0.71**	**Agreed**

Table 2 showed that all the 10 items had their mean values ranging from 3.55 to 3.96 which were above the cutoff point of 3.50. This is an indication that respondents accepted the items as the perceptions of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector. The table also showed that the standard deviations (SD) of the items ranged between 0.51 – 0.74 which indicated that the responses of the respondents were close to each other and the mean.

Table 3

Mean and Standard Deviation of Respondents on challenges to the adoption of wearable technologies in the Nigerian building construction sector **N=60**

S/N	Item Description	X	SD	Remark
1	Workers' resistance to the use of wearable devices and technologies during construction	3.96	0.63	Agreed
2	Workers' negative attitude/ignorance of the benefits of using wearable devices and technologies during construction	4.06	0.71	Agreed
3	The high initial cost of procurement of wearable devices and technologies by construction workers	4.63	0.67	Agreed
4	High training, maintenance, and operational costs of wearable devices and technologies	4.70	0.55	Agreed
5	Lack of well-trained personnel that will train construction workers on the appropriate and effective use of wearable devices and technologies during construction	3.55	0.67	Agreed
6	Bureaucratic changes in management and complications at construction sites can affect the acceptance of wearable devices and technology	3.69	0.66	Agreed
7	Lack of reliable data and critical information needed to integrate wearable devices into work processes, especially in developing nations like Nigeria	3.66	0.60	Agreed
8	The challenge of power supply	3.67	0.65	Agreed
9	Lack of proper information technology (IT) infrastructure	3.68	0.64	Agreed
10	Legal or ethical concerns	3.66	0.67	Agreed
	Grand Total	**3.34**	**0.77**	**Agreed**

Table 3 showed that all the 10 items had their mean values ranging from 3.55 to 4.70 which were above the cutoff point of 3.50. This shows that the respondents accepted the items as the challenges to the adoption of wearable technologies in the Nigerian building construction sector. The table also showed that the standard deviations (SD) of the items ranged between 0.55 – 0.70 which indicated that the responses of the respondents were close to each other and the mean.

3.1. Hypotheses

Table 4

A t-test analysis of building technology lecturers and building laboratory technologists on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector.

S/N	Respondents	N	$\bar{X}$	SD	df	t-cal	t-tab	Remark
1.	Building technology Lecturers	24	3.81	0.3				
					50	0.21	2.11	Not Significant
2.	Building technology lab-technologists	38	3.52	0.86				

Note: N= No of respondents, $\bar{X}$ = mean, SD= standard deviation, df = degree of freedom, t-cal = calculated value, t-tab = tabulated value, ns = not significant.

Table 4 revealed that the t-calculated value is 0.21 which is lower than the table value 2.11. This shows that there is no significant difference between the mean responses of building technology lecturers and building technology lab technologists. Therefore, the hypothesis that there is no significant difference in the mean responses of building technology lecturers and building laboratory technologists on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector was not rejected.

4. DISCUSSION

The data generated to answer research question one as presented in Table 1 showed the emerging wearable technologies that can be used in building construction. This finding is in agreement with Choi et al., (2017), who stated that smart vests containing lots of sensors are used to locate trackers, gyroscopes, and accelerometers. While this data includes the positioning of workers, it further includes details of posture, movements, and surroundings. Most of the time, these smart vests can be integrated with project management systems so that they can be more effective in their respective industry. This enables real-time data to be integrated into wider project analytics and allows resource usage, efficiency, and safety performance to be assessed in more detail. Nnaji and Awolusi, (2021) also supported the findings by stating that the use of smart helmets with sensors allows critical vital signs to be monitored in real-time, which makes the necessary action for accident situations or health problems reliable and speedy. Smart helmets are fitted with accelerometers that can detect sudden movements that could be associated with a crash, for example, a fall. Didehvar et al., (2018), stated that wristbands offer a practical solution for continuous Heart Rate (HR) monitoring without interference, making them better suited to continuous HR monitoring in situations where physical exertion is required. The reading of blood flow rates is obtained through Photoplethysmography (PPG) sensors used with automatic wristband-based heart-rate monitors. The performance of ECG sensors proves their ability the monitor HR wristbandbased using construction environments with accurate HR data.

The finding for research question two as presented in Table 2 revealed the perceptions of building technology lecturers on the adoption and implementation of wearable technologies for worker safety in the Nigerian building construction sector. The findings are in line with that of Nnaji et al., (2019), who stated that the major challenge is that wearable devices are relatively new and rarely used in the Nigerian construction industry. The second challenge is the low accuracy of data collected by wearable devices. The third challenge is the issue of data privacy. The other two challenges are the selectivity of physiological indicators characterizing attention changes and the limitations of the construction safety evaluation method, respectively. The finding is also supported by Brandt et al., (2018) who reveal a significant gap in research and experimental work on using wearable devices to monitor distraction in Nigerian construction workers. At present, there lack of reliable and comprehensive indicators for monitoring worker distraction on construction sites. Furthermore, while neurophysiological monitoring techniques such as electroencephalography (EEG) and electrocardiogram (ECG) have been developed to provide an objective real-time detection of mental fatigue, their dependence on recording the electrical activity of the human body, especially in Nigeria can be very invasive for workers. Moreover, the electrical signals can be easily affected by the harsh environment of the construction site, which raises concerns about the accuracy of the measurements.

The data generated to answer research question three as presented in Table 3 showed the challenges to the adoption of wearable technologies in the Nigerian building construction sector. This aligns with the findings of Moshood et al., (2020) who stated that most of the challenges preventing the adoption of wearable devices in Nigeria were cost-related. Some construction organizations are helpless due to the concern for the initial cost,

cost of training and employing professionals, and maintenance cost. Some organizations consider technology the roadblock to using safety technologies due to the need for adequate IT infrastructure and the immaturity of wearable technologies. Aghimien et al., (2019) also supported the findings by stating that the lack of competent staff to manage wearable technologies for construction companies and organizations was the last barrier preventing construction organizations from using the technology. Construction professionals in public sectors, consultancy, and contracting firms are the participants of this study. Every construction practitioner, including lower management staff such as foremen and laborers, is expected to use wearable technologies. However, Mahmud et al., (2022) suggest that this category of construction workers may hold perceptions different from the opinions of construction professionals concerning benefits derivable from using wearable safety technologies and factors affecting their adoption.

5. CONCLUSION

The study examined the perception of building technology lecturers on the adoption of wearable technologies for worker safety in Nigeria's building construction sector. The study found that building technology lecturers had a low perception of poor implementation of wearable devices and technologies by builders in Nigeria. The study concludes by stating that adopting the newest wearable technologies can make a construction site safer and more secure by preventing unexpected accidents and injuries. Therefore, efforts should be made by builders to incorporate wearable construction technologies that enhance worker safety while simultaneously streamlining tasks and increasing productivity.

The following recommendations are made based on the findings of the study:

1. There should be regular public awareness, through advocacy programs, of the benefits of the adoption and implementation of wearable devices among building construction workers in Nigeria.

2. There should be synergy-building among relevant professionals in the building industry building regulation in Nigeria to ensure the enforcement of proper penalties against erring builders who fail to implement the use of wearable technologies for their workers.

Conflict of interest: No potential conflict of interest was reported by the authors.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

Abdalfatah, Z., Elbeltagi, E., & Abdelshakor, M. (2023). Safety performance evaluation of construction projects in Egypt. *Innovative infrastructure solutions*, *8*(9), 240. https://link.springer.com/article/10.1007/s41062-023-01181-y

Abina, O. G., Ogunbayo, B. F., & Aigbavboa, C. O. (2023). Enabling technologies of health and safety practices in the fourth industrial revolution: Nigerian construction industry perspective. *Frontiers in Built Environment*, *9*, 1233028. https://www.frontiersin.org/articles/10.3389/fbuil.2023.1233028/full

Abuwarda, Z., Mostafa, K., Oetomo, A., Hegazy, T., & Morita, P. (2022). Wearable devices: Cross benefits from healthcare to construction. *Automation in Construction*, *142*, 104501. https://www.sciencedirect.com/science/article/pii/S0926580522003740

Aghimien, D., Aigbavboa, C., & Oke, A. (2019). A review of the application of data mining for sustainable construction in Nigeria. *Energy procedia*, *158*, 3240-3245. https://www.sciencedirect.com/science/article/pii/S1876610219310483

Balkhyour, M. A., Ahmad, I., & Rehan, M. (2019). Assessment of personal protective equipment use and occupational exposures in small industries in Jeddah: Health implications for workers. *Saudi journal of biological sciences*, *26*(4), 653-659. https://www.sciencedirect.com/science/article/pii/S1319562X1830161X

Brandt, M., Madeleine, P., Samani, A., Ajslev, J. Z., Jakobsen, M. D., Sundstrup, E., & Andersen, L. L. (2018). Effects of a participatory ergonomics intervention with wearable technical measurements of physical workload in the construction industry: cluster randomized controlled trial. *Journal of medical internet research*, *20*(12), e10272. https://www.jmir.org/2018/12/e10272/

Choi, B., Hwang, S., & Lee, S. (2017). What drives construction workers' acceptance of wearable technologies in the workplace? Indoor localization and wearable health devices for occupational safety and health. *Automation in Construction*, *84*, 31-41. https://www.sciencedirect.com/science/article/pii/S0926580517307215

Dang, K., Elelu, K., Le, T., & Le, C. (2022). Augmented Hearing of Auditory Safety Cues for Construction Workers: A Systematic Literature Review. *Sensors*, *22*(23), 9135. https://www.mdpi.com/1424-8220/22/23/9135

Didehvar, N., Teymourifard, M., Mojtahedi, M., & Sepasgozar, S. (2018). An investigation on virtual information modeling acceptance based on project management knowledge areas. *Buildings*, *8*(6), 80. https://www.mdpi.com/2075-5309/8/6/80

Dithebe, K., Aigbavboa, C. O., Thwala, W. D., & Malabela, A. T. (2019). Descriptive perspective on factors affecting the complete adoption of information technology systems in construction firms. In *Journal of Physics: Conference Series* (Vol. 1378, No. 2, p. 022045). IOP Publishing. https://iopscience.iop.org/article/10.1088/1742-6596/1378/2/022045/meta

Dong, S., Li, H., & Yin, Q. (2018). Building information modeling in combination with real-time location systems and sensors for safety performance enhancement. *Safety Science*, *102*, 226-237. https://www.sciencedirect.com/science/article/pii/S092575351730704X

Ercan, İ. P., & Timur, Ş. (2020). Changing Terminology of Definition and Design of Wearable Technology Products. *Online Journal of Art and Design*, *8*(3), 90-106. http://www.adjournal.net/articles/83/837.pdf

Kim, B., Sri Preethaa, K. R., Song, S., Lukacs, R. R., An, J., Chen, Z., ... & Kim, S. (2024). Internet of Things and ensemble learning-based mental and physical fatigue monitoring for smart construction sites. *Journal of Big Data*, *11*(1), 115. https://link.springer.com/article/10.1186/s40537-024-00978-7

Lee, C., Kim, M., Ahn, H., Yoo, W. S., Cho, H., & Choi, Y. (2023). Developing a field-oriented analytical safety assessment model for construction workers. *KSCE Journal of Civil Engineering*, *27*(10), 4085-4100. https://link.springer.com/article/10.1007/s12205-023-1978-8

Mahmud, D., Bennett, S. T., Zhu, Z., Adamczyk, P. G., Wehner, M., Veeramani, D., & Dai, F. (2022). Identifying facilitators, barriers, and potential solutions for adopting exoskeletons and exosuits in Construction workplaces. *Sensors*, *22*(24), 9987. https://www.mdpi.com/1424-8220/22/24/9987

Moshood, T. D., Nawanir, G., Sorooshian, S., Mahmud, F., & Adeleke, A. Q. (2020). Barriers and benefits of ICT adoption in the Nigerian construction industry. A comprehensive literature review. *Applied System Innovation*, *3*(4), 46. https://www.mdpi.com/2571-5577/3/4/46

Nnaji, C., & Awolusi, I. (2021). Critical success factors influencing wearable sensing device implementation in the AEC industry. *Technology in Society*, *66*, 101636. https://www.sciencedirect.com/science/article/pii/S0160791X21001111

Nnaji, C., Awolusi, I., Park, J., & Albert, A. (2021). Wearable sensing devices: towards the development of a personalized system for construction safety and health risk mitigation. *Sensors*, *21*(3), 682. https://www.mdpi.com/1424-8220/21/3/682

Nnaji, C., Gambatese, J., Karakhan, A., & Eseonu, C. (2019). Influential safety technology adoption predictors in construction. *Engineering, Construction and Architectural Management*, *26*(11), 2655-2681. https://www.emerald.com/insight/content/doi/10.1108/ECAM-09-2018-0381/full/html

Oke, A. E., Arowoiya, V. A., & Akomolafe, O. T. (2022). Influence of the Internet of Things application on construction project performance. *International Journal of Construction Management*, *22*(13), 2517-2527. https://www.tandfonline.com/doi/abs/10.1080/15623599.2020.1807731

Okoye, P. U. (2018). Occupational health and safety risk levels of building construction trades in Nigeria. *Construction Economics and Building*, *18*(2), 92-109. https://search.informit.org/doi/abs/10.3316/INFORMIT.755410678319746

Okpala, I., Nnaji, C., & Awolusi, I. (2019). Emerging construction technologies: State of standard and regulation implementation. In *ASCE International Conference on Computing in Civil Engineering 2019* (pp. 153-161). Reston, VA: American Society of Civil Engineers. https://ascelibrary.org/doi/abs/10.1061/9780784482438.020

Pillai, M. V., Van Engelhoven, L., & Kazerooni, H. (2020). Evaluation of a lower leg support exoskeleton on the floor and below hip height panel work. *Human factors*, *62*(3), 489-500. https://journals.sagepub.com/doi/abs/10.1177/0018720820907752

Sadhu, A., Peplinski, J. E., Mohammadkhorasani, A., & Moreu, F. (2023). A review of data management and visualization techniques for structural health monitoring using BIM and virtual or augmented reality. *Journal of Structural Engineering*, *149*(1), 03122006. https://ascelibrary.org/doi/abs/10.1061/(ASCE)ST.1943-541X.0003498

Zhao, J., Du, X., Guo, H., & Li, L. (2024). Risk management and its relationship with innovative construction technologies with a focus on building safety. *International Journal of System Assurance Engineering and Management*, *15*(8), 4050-4068. https://link.springer.com/article/10.1007/s13198-024-02410-y